BBC

ROSETTA'S COMET CAPTURE MISSION

How one spacecraft could uncover the Universe's oldest secrets

FOCUS

SCIENCE AND TECHNOLOGY

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ISSUE 271 / AUGUST 2014

Organs on demand
The new era of transplants begins

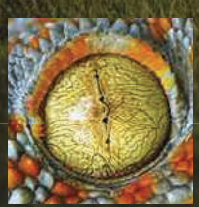
World War I
The scientific legacy

Antibiotic resistance
Is the solution in your backyard?

TAKE CONTROL OF YOUR DREAMS

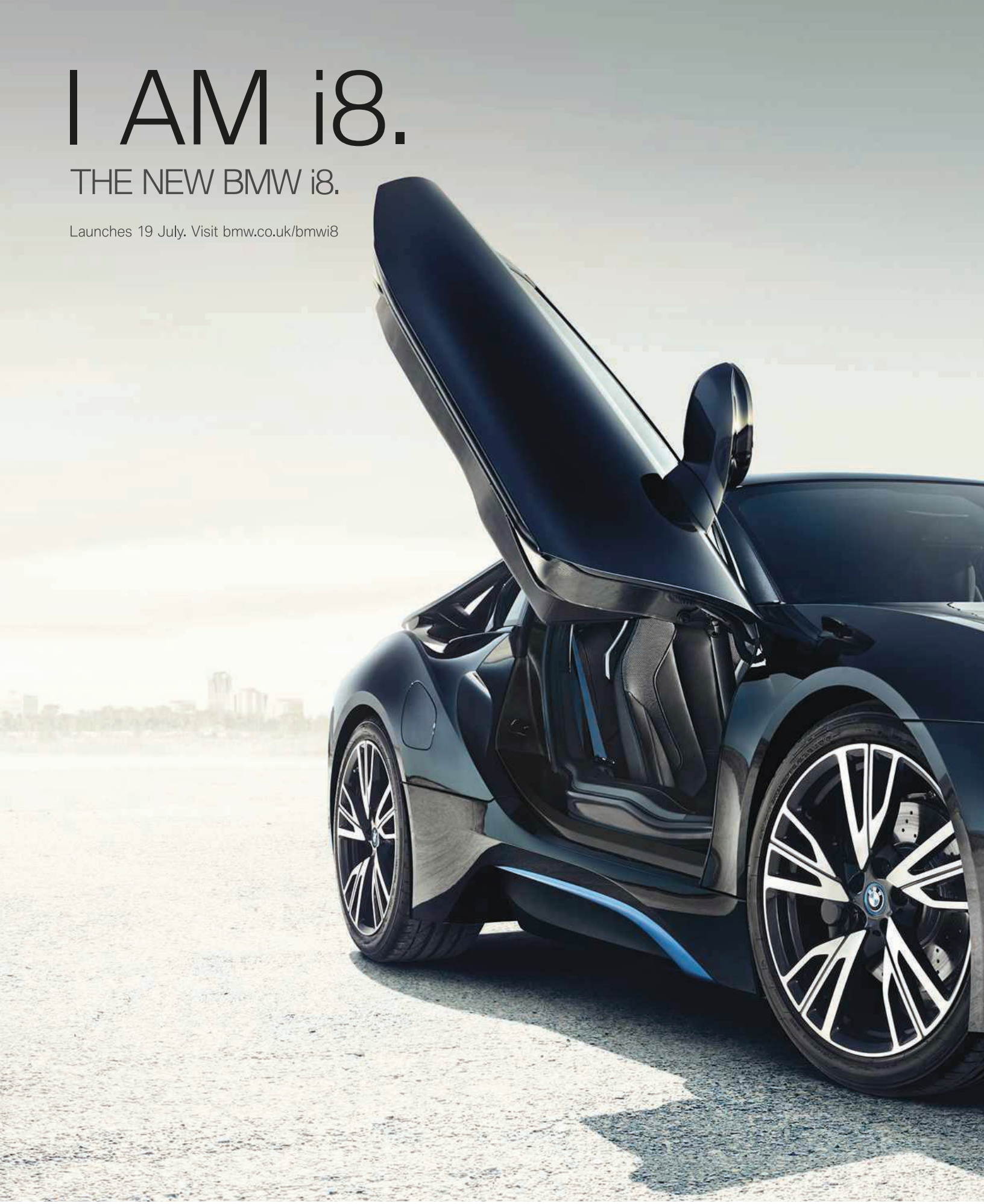
The scientific breakthrough that unlocks the brain's limitless power while you sleep

SUPERSENSES
Meet the animals that feel electricity, see UV and taste with their entire bodies



Q&A
- How loud was the Big Bang?
- If you're allergic to penicillin, can you eat Stilton?
- Can a dead sun be reignited?

SUMMER SPEAKERS
TESTED: the best wireless audio money can buy



Official fuel economy figures for the BMW i8: Weighted combined cycle: mpg 134.5 (2.1 l/100 km), CO_2 emissions 49 g/km, power output combined cycle) 11.9 kWh, customer-orientated total range up to 373 miles. Maximum electric range value 23 miles, common average electric characteristics and preconditioning. The BMW i8 is a plug in hybrid electric vehicle that requires mains electricity for charging.

BMW i

The Ultimate Driving Machine

(engine) 170/231 kW/hp, power output (electric motor) 96/131 kW/hp, total average energy consumption per 62 miles/100 km (weighted range value (e-Drive only) up to 23 miles. Figures may vary depending on different factors, including but not limited to individual driving style, climatic conditions, route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WELCOME

WOULD YOU LIKE to visit Mars? Go on a date with a movie star? Wear the yellow jersey in the Tour de France? They're the sort of things we might dream about doing. And now science has come up with a way to put you into a dream that you can control. Rita Carter slips into the fascinating dream world on p37.

This month is an exciting one for space exploration. The Rosetta spacecraft, launched in 2004, is about to arrive at Comet 67P/Churyumov–Gerasimenko. It'll go into orbit around the comet in readiness for dispatching a lander in November – the first time a human-made spacecraft will land on a comet's surface. Will Gater brings you more details on p56.

This issue of *Focus* will be on sale on 28 July 2014 – the 100th anniversary of the outbreak of World War I. That conflict resulted in the deaths of millions of servicemen, but many wartime innovations went on to change our lives for the better. Ned Lebow reveals some of the war's more surprising outcomes on p54.

Today, the demand for new antibiotics is becoming ever more urgent, as bacteria become resistant to common varieties. But strange as it may sound, your back garden might help scientists come up with a new wonder drug – Zoe Cormier explains why on p74. Enjoy the issue!

Graham Southorn, Editor

Don't miss our September issue, on sale 21 August 2014

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THIS MONTH WE...

...went to Tokyo to see Epson's new smart glasses, Moverio. Can this Android-friendly headgear rival the much-hyped Google Glass? Stay tuned for a full review next issue!

...explored the future of transport at the Imovation Centre in Milton Keynes, finding out how social media, self-driving cars and integrated IT systems will transform the way we travel.

...talked to Tracey Brown, director of Sense About Science, about the strange safety rules that govern our lives. Listen to our chat on this month's podcast.

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APPEARING IN THIS ISSUE...

Rita Carter

Rita is a journalist and author specialising in neuroscience and psychology. Her latest book, on personality, is *The People You Are*. She discusses lucid dreaming on p37.

Helen Czerski

Our columnist presents *Beyond Human*, a new series coming soon to BBC Two and exploring incredible animal senses. She reveals some extraordinary animal abilities on p46.

Zoe Cormier

The author of our antibiotics feature on p74 is a science journalist with a background in biology and zoology, and a member of the Guerrilla Science collective.

Ned Lebow

A professor in the Department of War Studies at King's College London, Ned talks us through some of the scientific breakthroughs to come out of WWI on p54.

WANT TO SUBSCRIBE? Turn to p32 to **save 35%** on the shop price of *BBC Focus*

SUBSCRIBER BONUS On p32, planetary scientist **Dr Peter Grindrod** talks us through the current key issues in Martian science

COVER: MAGICTORCH

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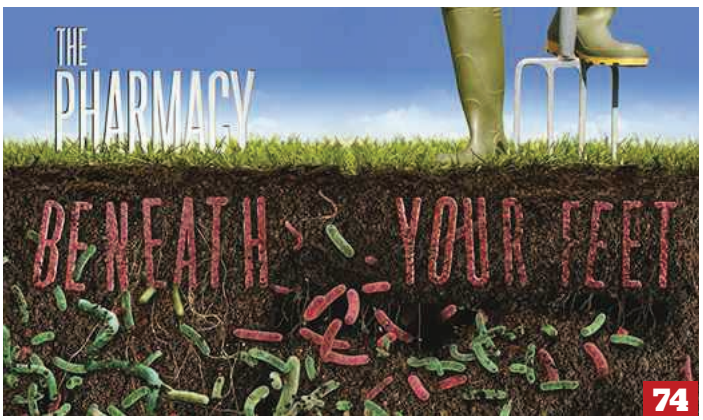

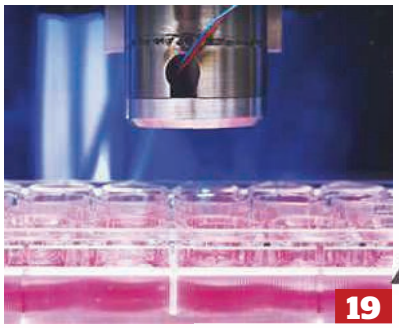

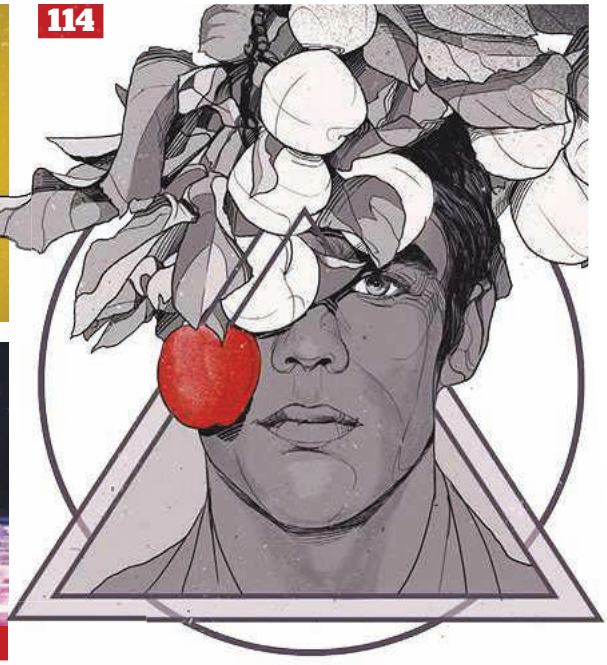

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Awe-inspiring images from the world of science

MegaPixel

Military mannequin

THIS CHARACTER IS Porton Man, the Ministry of Defence's newest robot. Taking its name from Porton Down, the home of the Defence Science and Technology Laboratory, it is used to test the effectiveness of protective military clothing.

"We have designed software that enables the figure to run and walk at different speeds and with different styles of movement, such as a high-stepping march," says Jez Gibson-Harris, director at i-bodi, the company that built Porton Man. "The figure, made out of carbon composites, can simulate sitting, kneeling and sighting a gun in a realistic manner. The head is wirelessly controlled and can rotate and tilt."

After decking him out in state-of-the-art protective clobber, Ministry of Defence scientists then bombard Porton Man with all manner of chemical and biological weapons. The 276 sensors – the metallic pits all over his body – record exactly how much damage makes it through the protective gear.

PHOTO: PRESS ASSOCIATION

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MegaPixel

Cave of clouds

DEEP BELOW GROUND, a caver is enshrouded in cloud. Her flashlight shines into the void, illuminating the distant figure of another explorer dangling 150m above the floor. This remarkable picture was captured during a 2012 expedition to the Er Wang Dong cave system in China's Wulong County, led by American caver Erin Lynch.

Inside Cloud Ladder Hall, one of the world's largest subterranean spaces, humid air enters via openings near the ground. This air becomes trapped within the cavern, a tiny passage at roof level providing the only exit.

"Without sunlight, the air in the cave will be cool, and is likely being fed with moisture from water passing through the permeable limestone rocks," says Dr Jon Shonk, a meteorologist at the University of Reading. "As a result, the air will be permanently saturated with water vapour. It's the condensation of this water vapour that forms the underground clouds."

PHOTO: ROBBIE SHONE

MegaPixel

Soft landing

ENGINEERS AT NASA'S Jet Propulsion Laboratory in Pasadena, California are seen here putting their latest marvel through its final checks. The flying saucer-like vessel is known as the Low-Density Supersonic Decelerator (LDSD) and has been designed to transport heavier payloads to the surface of Mars.

As if getting vehicles to the Red Planet wasn't tricky enough, slowing them down once they get there presents further problems. "The atmosphere of Mars is very thin, about one per cent the density of Earth's," explains Ian Clark, LDSD principal investigator at JPL. "This means that there are fewer particles to bounce off our entry vehicle to produce aerodynamic drag and slow it down. As vehicles grow larger, the mass grows faster than the drag produced, which means we cannot slow down as well."

The solution is an inflatable tube around the vehicle's rim, called the Supersonic Inflatable Aerodynamic Decelerator. This inflates like an airbag, increasing the surface area of the vehicle, and therefore drag. A more traditional landing parachute is then employed to further slow the vehicle.

The craft had a successful test launch at the end of June over Hawaii. Further test flights are now scheduled for next year.

PHOTO: NASA/JPL


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MESSAGE OF THE MONTH

John White has been pondering the cultural aspects of human hearing

The bells, the bells!

I was very interested in Helen Czerski's article (July, p35), in particular how the brain interprets harmonic resonances and 'fills in' the fundamental frequency – even if it is not actually present in the sound of the bell. I'm interested to know if this is as a result of our auditory experience based in Western culture and the eight-note scale, or whether it is an innate, deep-rooted attribute of our brain structure.

There are cultures where different scales have been used traditionally. The standard octave with tones and semi-tones has little relevance in their music, and their melodies and harmonies are often 'alien' to our ears – though with increased exposure they are less alien and more commonplace. It would be an interesting experiment to see if the observations were the same for a listener who had never been exposed to Western harmonics, if there are any left in the world.

Perhaps to them the experience of Big Ben would be entirely different?

John White

Helen Czerski replies: *I wondered that as well, but I haven't been able to find the answer. Even though not all scales are based on our octave, humans definitely respond to full octaves. As far as I know, all musical scales consider a doubling or halving of the frequency to have a special relationship to the original note. It may be that you'd have to tune the bells differently in different cultures, but I think that you'd be able to recreate the effect everywhere.*

Write in and win!

The writer of next issue's 'Message of the month' wins a Supertooth D4 speaker, worth £49.99. The portable, megaphone-style 8W wireless speaker pairs with compatible smartphones and other devices using Bluetooth or NFC, and comes in five colours. It's available from www.johnlewis.com

The Hawking apocalypse

Regarding the feature 'Making black holes on Earth' (Summer, p77). It's all very well saying that micro black holes would evaporate almost instantly [via Hawking radiation], but has Hawking radiation been verified with data, or is it just a mathematical model? I wonder how it could have been verified with data as we cannot observe black holes – only their effect! I think before CERN tries this experiment, observational evidence for the existence of Hawking radiation is a necessity, otherwise it could be a Hawking apocalypse on Earth!

John Bradbury, Norfolk

Rights for robots

I enjoyed Stephen Baxter's article on robot rights (July, p37) but can't help but feel that your conclusion may be a negative one. History, sadly, illustrates humanity's flaws with regard to the slave trade and the media is full of modern examples of human trafficking. It seems inevitable that future generations of robots will face the same fate: treated simply as machines to do our bidding.

When the day comes that the first of these machines is granted any form of rights, I don't think the reaction of the robot community will be one of judgement and possible repercussions. One would hope that the logic and superior intelligence of this future species would dictate that they look upon us with robot sadness as the flawed beings we are, and try to educate rather than punish.

Simon Thomas

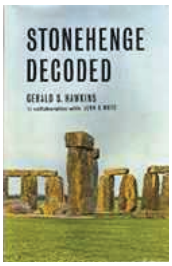
If robots are definitely sentient, they should share human rights. On the other hand, will they really want them? If humans create and program the robots, we can choose how they think. If we want a robot to work at a supermarket till, wouldn't we simply ensure that the droid's only ambitions are to sell things and converse lightly with the customer?

I understand that some would say this can't truly be sentience. However, its

ILLUSTRATOR: CIARA PHELAN, ANDY POTTS

emotions are triggered by particular stimuli, which vary depending on the droid's purpose.
Sofia Spencer, Harrogate (aged 12)

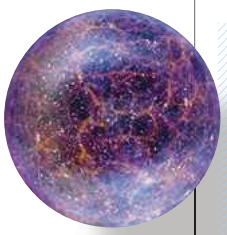
Stonehenge secrets



The feature 'Secrets of the stones' (July, p48) makes no significant mention of the site's location in relation to astronomy, as detailed in Gerald S Hawkins's book *Stonehenge Decoded*. Briefly, only at this latitude do the midsummer sunrise and midwinter moonset occur at right angles, which was apparently of significance to the ancients and is marked by the positioning of the 'Station Stones'.

From this base rectangle, many of the other stones marked significant astronomical alignments shown in the book. All this must surely have been significant in placing the monument. Hawkins goes on to show that the 56 'Aubrey' stones could have been used to compute the probability of eclipses.
Peter Wenham, Braunston

Before or after?



In 'Welcome to the Multiverse' (July, p39), John Gribbin writes "the crucial point is that inflation came before the Big Bang". Hold on, what can expand exponentially before the Big Bang? How does he define the Big Bang? Gribbin contradicts Andre Linde himself, who referred to "a billionth of a billionth of a billionth of a millionth of a second after the Big Bang" on the day he received the news of the success of the BICEP2 experiment at the South Pole.

I also looked at NASA's website, and read: "Our Universe burst into existence in an event known as the Big Bang 13.8 billion years ago. Moments later, space itself ripped apart, expanding exponentially in an episode known as inflation."

So who is right?
Carol Hadwen

John Gribbin replies: *The Big Bang starts at the time when the Universe had the density of an atomic nucleus. Inflation explains how it got from a quantum fluctuation with the Planck density (see bit.ly/1jdjx7E) to that density.*

Multiverse mystery

In his article (July, p39), John Gribbin mentions four different possible types of multiverse as if they're exclusive. Couldn't the Multiverse, if it exists, be made in any or all of these ways? And possibly other ways nobody has thought of yet?
Richard Vallis

John Gribbin replies: *Absolutely! In the Multiverse, all things are possible.*

Genius schmenius

I was interested to see the piece on 'the greatest genius' (Summer, 46). I quickly became baffled instead, seeing Jobs and Zuckerberg's faces on the cover alongside Curie, Da Vinci and Einstein.

Having read the preamble I think you have fudged your criteria. Genius might be a difficult term to define in any meaningful way, but the same holds true of 'individual achievement' and 'influence'. It seems to me (and you'll probably be able to tell that I am not one to camp out overnight outside Apple stores) that if Jobs and Zuckerberg have a field in which they might be judged as geniuses, it's probably in marketing more than anything else, and that seems a poor thing to celebrate alongside a list of the greatest scientific thinkers from human history.
Simon Bartlett

YOUR COMMENTS ON TWITTER & FACEBOOK

We asked: Was Facebook's 'emotion experiment', which affected nearly 700,000 users, justified?

Alison Shields The media has been telling us what to think for years, what's new?

@Rich_141 'Test, measure, analyse, repeat'. At no point does the word 'Like' appear in that process.

@JCC_82 I don't like the idea of Facebook's dodgy behaviour being justified by packaging it as science.

Join the discussion at twitter.com/sciencefocus and facebook.com/sciencefocus

Oops!

• Stephen Baxter's column in the Summer issue referred to 'Sarajevo, Serbia'. Sarajevo is, in fact, in Bosnia and Herzegovina.

FOCUS
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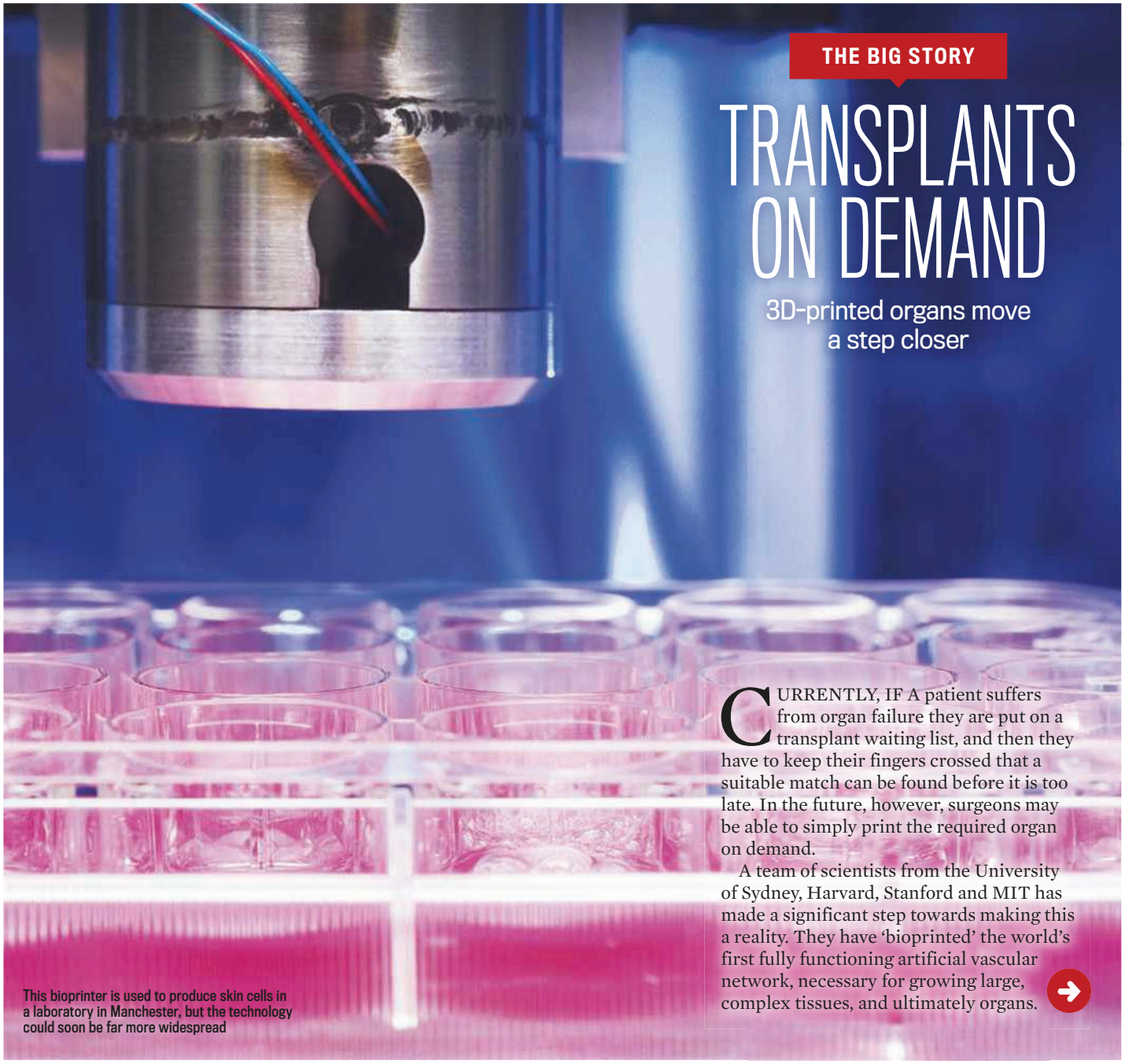
FRACKED OFF?
David Shukman on the furore around hydraulic fracturing

FISH-EATING SPIDERS
A new study has turned up some surprises about arachnids' diets

SPACE ROCK
900 light-years away, there's a diamond the size of a planet



THE BIG STORY

TRANSPLANTS ON DEMAND

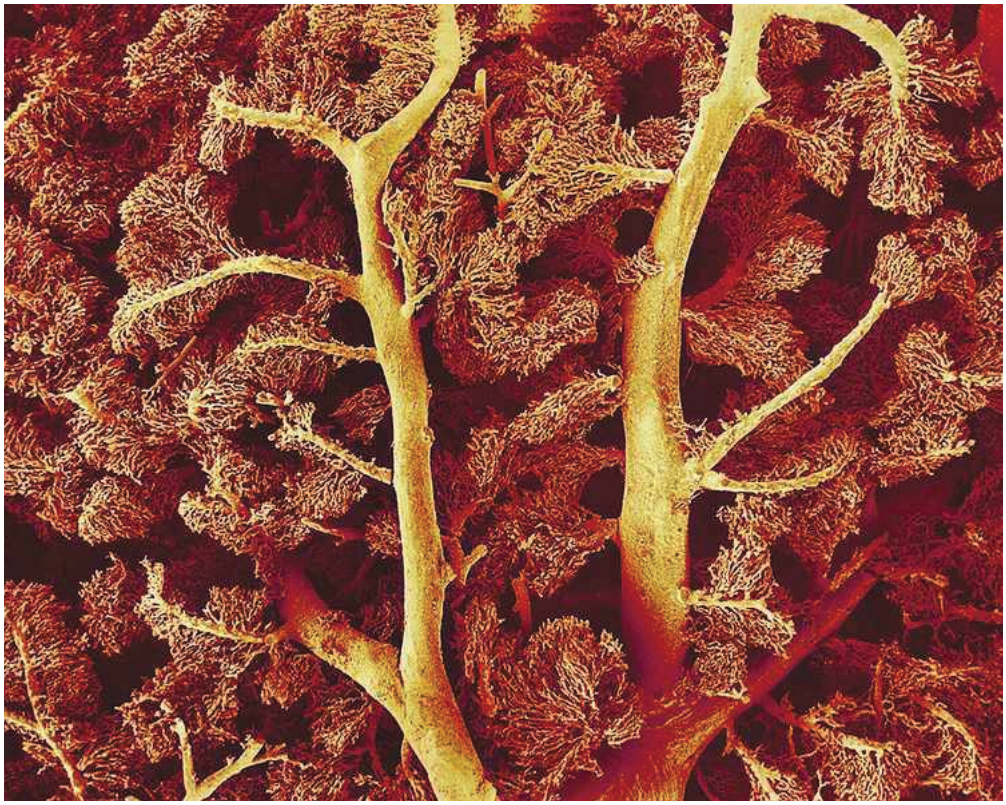
3D-printed organs move a step closer

CURRENTLY, IF A patient suffers from organ failure they are put on a transplant waiting list, and then they have to keep their fingers crossed that a suitable match can be found before it is too late. In the future, however, surgeons may be able to simply print the required organ on demand.

A team of scientists from the University of Sydney, Harvard, Stanford and MIT has made a significant step towards making this a reality. They have 'bioprinted' the world's first fully functioning artificial vascular network, necessary for growing large, complex tissues, and ultimately organs.

This bioprinter is used to produce skin cells in a laboratory in Manchester, but the technology could soon be far more widespread

PHOTO: SCIENCE PHOTO LIBRARY



This image of the dense network of blood vessels in the liver reveals the challenge facing scientists in printing organs

"Thousands of people die each year due to a lack of organs for transplantation," says Dr Luiz Bertassoni, lead author of the study. "Imagine being able to walk into a hospital and have a full organ printed with all the cells, proteins and blood vessels in the right place, simply by pushing the 'print' button on your computer screen. We are still far away from that, but our findings are an important new step towards achieving these goals."

The researchers created the network of artificial blood vessels by using a high-tech bioprinter to create a tangle of interconnected tiny fibres to serve as a mould. They covered this structure with a cell-rich, protein-based material, which was solidified using light. Finally, they removed the bioprinted fibres to leave behind a network of human endothelial cells, which form the lining of blood vessels. After a week these cells self-organised into stable capillaries.

Cells need ready access to nutrients, oxygen and an effective waste disposal system to sustain life. This is why 'vascularisation' – the building of a functional transportation system for all of the above – is central to the engineering of biological tissues and organs.

"One of the greatest challenges to the engineering of large tissues and organs is growing a network of blood vessels and capillaries," says Dr Bertassoni. "Cells die without an adequate blood supply because blood delivers oxygen that's necessary for cells to grow and perform a range of functions. Replicating the complexity of these networks has been a stumbling block preventing tissue engineering from becoming a real-world clinical application.

"While recreating little parts of tissues in the lab is something that we have already been able to do, the possibility of printing 3D tissues with functional blood capillaries in the blink of an eye is a game-changer," he says.

ANALYSIS

Prof Gurch Randhawa

Director of the Institute for Health Research, University of Bedfordshire

"THE CURRENT breakthrough of producing artificial vascular networks is an important first step towards developing bioprinted organs.

There continues to be a worldwide shortage of organs for transplant, so bioprinted organs offer the prospect of being able to create individually matched organs for patients. Currently there are nearly 10,000 people waiting for a transplant in the UK. Last year, there were 4,212 transplants carried out. It will be an exciting innovation that could potentially solve this shortage of organs for transplant in the future.

Bioprinted organs offer the possibility of a 'print on demand' service, thereby reducing the need for long-term storage, which is currently a significant problem as conventional organs cannot be stored for very long. Another potential advantage of bioprinted organs is that although all organs carry a risk of rejection when transplanted, the possibility of bioprinting organs to suit each individual patient would potentially reduce the risk of organ rejection.

In the long term, bioprinted organs have the potential to increase the number of organs available for transplant, and so save more lives. However, it is unlikely that we will see the technology in hospitals any time soon. It is difficult to predict how long it will take to create implantable bioprinted organs, but history tells us that such technological developments tend to take decades, rather than years."

TIMELINE

A brief history of organ transplants

1902

Alexis Carrel demonstrates the joining of blood vessels, a process that makes organ transplants feasible for the first time.

1954

Joseph Murray performs the world's first successful living kidney transplant in Boston, Massachusetts.

1963

At the University of Colorado, Thomas Starzl carries out the first successful liver transplant. The transplanted organ functions for 13 months.

2012

San Diego-based medical research company Organovo successfully 3D-prints a tiny liver. It functions for five days.

PHOTO: SCIENCE PHOTO LIBRARY, ORGANOVO, GETTY X2

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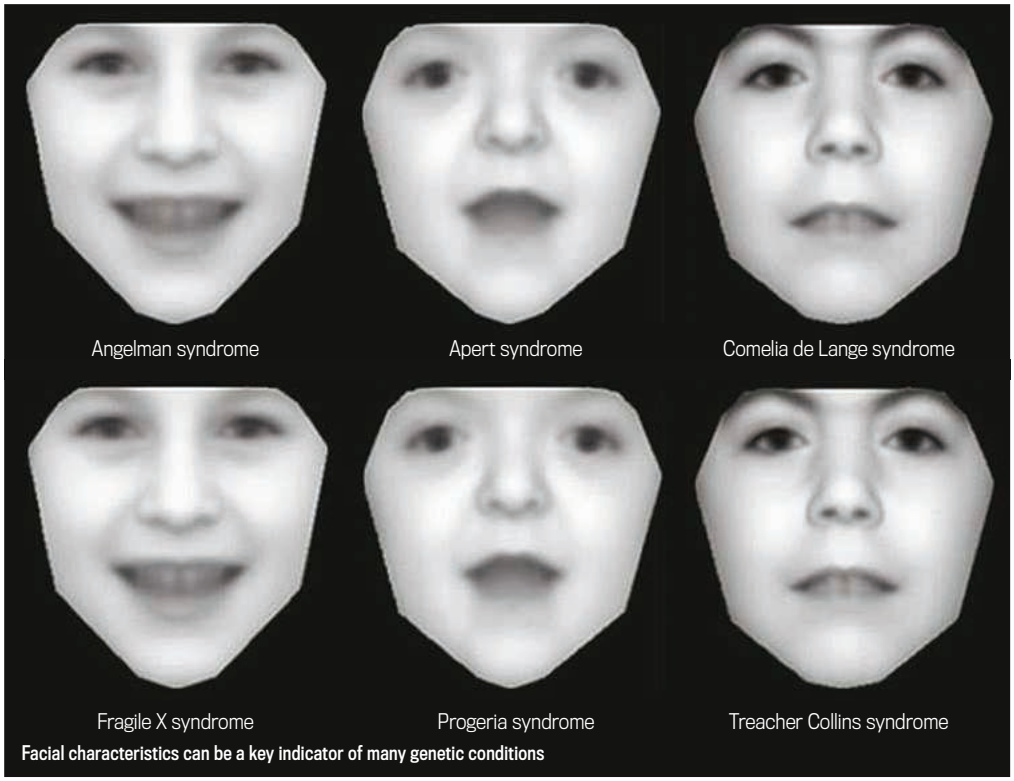
1 MINUTE EXPERT
Gliese 832c

What's that? A new eight-bladed men's shaving razor?
Nope, way off. Light-years away. Sixteen light-years, to be precise, as Gliese 832c is in fact the latest Earth-like exoplanet to be discovered.

So where is it?
It is located in the Grus constellation orbiting Gliese 832, a red dwarf star that has about half the mass and radius of the Sun.

Who found it?
It was discovered by Chris Tinney and a team at the University of New South Wales using data collected by the Anglo-Australian Telescope, the 6.5-metre Magellan Telescope and the European Southern Observatory 3.6-metre telescope.

How will knowing about it benefit us?
Well, its mass is 5.4 times that of Earth and it has an orbital period of just 35.68 days, but despite these differences from our planet it receives roughly the same energy from Gliese 832 as the Earth does from the Sun, and so is likely to have Earth-like surface temperatures. The Earth Similarity Index of Gliese 832c (0.81) puts it in the top three most Earth-like planets so far discovered. The other two close Earth analogues are Gliese 667Cc (0.84) and Kepler-62e (0.83). However, as it is the closest to Earth of the three it holds great promise for further obsertvations.



Facial characteristics can be a key indicator of many genetic conditions

HEALTH

Facing up to genetic disorders

THE LAST TIME most of us looked through our childhood photo album, it was likely thanks to a parent trying to embarrass us in front of a new girl or boyfriend. However, researchers at Oxford University have used pictures of children to create software capable of diagnosing genetic disorders.

It's thought that 30 to 40 per cent of rare genetic disorders involve some form of change in the face and skull, possibly due to the number of genes involved in the growth of the face and cranium as a baby develops in the womb. Taking this as their starting point, the team has developed a computer program capable of mapping facial structures by identifying corners of the eyes, nose, mouth and other features. It then compares these maps against what it has learnt from other photographs fed into it, and can identify key indicators of conditions such as Down's syndrome or Angelman syndrome.

"A diagnosis of a rare genetic disorder can be a very important step. It can provide parents with some certainty and help with genetic counselling on risks for other children or how likely a condition is to be passed on," says lead researcher Christoffer Nellaker.

"In future, a doctor anywhere in the world should be able to take a smartphone picture of a patient and run the computer analysis to quickly find out which genetic disorder the person might have," he added.

NEUROSCIENCE

You decide?

EVER MADE A bad decision? Don't worry – just blame it on your brain's background noise! Our ability to make choices may, it seems, be influenced by random electrical fluctuations in the brain.

In a study carried out at the University of California, Davis, volunteers were asked to focus on the centre of a screen and to look left or right when a cue symbol flashed up. The researchers found that by monitoring electrical activity in the brain shortly before the cue appeared, and therefore before the volunteers knew they were going to make a choice, they could predict the likely outcome of that choice.

"The state of the brain just before presentation of the cue determines whether you will attend to the left or to the right," said researcher Jesse Bengson.

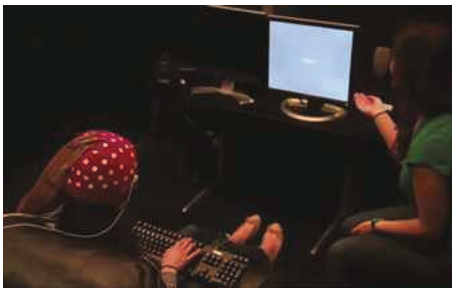

Is free will just an illusion? New evidence suggests that electrical 'noise' in the brain influences many of our decisions

PHOTO: CHRISTOFFER NELLÅKER/UNIVERSITY OF OXFORD. CHRIS JORDAN-BLOCH/EARTHJUSTICE. UNIVERSITY OF CALIFORNIA DAVIS ILLUSTRATOR: DEM ILLUSTRATION

To frack or not to frack? That is the question...

DAVID SHUKMAN
The science that matters

California resident Walt Desatoff and the oilfield next door

FRACKING WILL POLLUTE our drinking water and exacerbate climate change. Alternatively, the process will be handled carefully and give us plentiful, homegrown energy. Which is right? There is no easy answer.

In California last year, I met a man called Walt Desatoff who had watched a field of roses next to his house transformed into an industrial wasteland. A company had turned up to search for oil, but things did not go according to plan. When the drillers fracked a layer of shale, they unexpectedly released vast quantities of gas. The gas had to be burned off in a flare so violent that it could not be tamed for weeks. The distraught homeowner had no option but to move away.

Extracting oil or gas from shale requires more effort than getting it from conventional sources. In Kuwait, I once saw oil seeping out of the ground under natural pressure. By contrast, shale holds hydrocarbons so tightly that it needs to be fractured for any of them to be released. This is done by blasting water into the rock under massive pressure. The process is uglier than many of its supporters would have you believe, but it can also be done more safely than protestors might care to admit.

At one site, in the scrublands of southern Texas, I watched a semicircle of trucks lined up as if in military formation, each one carrying a pump that was connected by twisting orange hoses to the wellhead. Added to the flow are various chemicals and tiny grains known as 'proppants', which hold open the newly formed fractures in the shale to encourage the oil and gas to flow out. The site was well-kept and orderly and, crucially, there were no houses for miles around.

Compared to any other kind of industrial activity, it did not seem unusually disturbing, and the operators pointed to a record of a million 'frack jobs' in the United States so far with very few categorically proven problems. But here's the key question for our more crowded island: would you want it going on next door?

DAVID SHUKMAN is the BBC's Science Editor. @davidshukmanbbc

THEY DID WHAT?!

Salad resembling famous artwork given to diners

What did they do?
A team at the University of Oxford made three salads out of identical ingredients: one arranged neatly, one thrown together in the centre of the plate and one arranged to look like Wassily Kandinsky's *Painting Number 201*. They then asked 60 participants to rate the three salads for flavour and enjoyment.

Why did they do that?
To investigate how diners' perception of flavour is influenced by other senses, and how the presentation of food can affect its appeal.

What did they find?
Not only did the diners find the artistically pleasing creation tastiest, they were also willing to pay twice as much for it. The researchers say the results could help to encourage people to eat a healthier diet.

Research into whether spiders are fond of pickled eggs is still ongoing

ZOOLOGY

Spiders are partial to a fish supper

IT'S NEWS THAT'S likely to send arachnophobes running for the hills: spiders have been observed eating fish. Don't fret, they're not working their way up the food chain.

Although spiders are typically thought of as predators of insects, a team at the University of Basel, Switzerland and University of Western Australia has catalogued five families of spider that hunt fish in the wild.

"The finding of such a large diversity of spiders engaging in fish predation is novel. Our evidence suggests that fish might be an occasional prey item of substantial nutritional importance," says study co-author Martin Nyffeler.

"Fish meat is high quality in terms of protein content and caloric value," adds Nyffeler. "Feeding on fish may be particularly advantageous during the mating period, when the elevated energy and protein requirements of pregnant female spiders require increased food intake, or at times of limited availability of invertebrate prey."

These semi-aquatic, fish-eating spiders typically live around the edges of shallow freshwater streams, ponds or swamps. A number of them are also capable of swimming, diving or walking across the water surface itself. They use potent neurotoxins to disable the fish and have powerful enzymes that enable them to digest fish up to twice their own size. The feeding process usually lasts several hours, researchers say.

But fear not: although fish-eating spiders can be found on all continents save for Antarctica, they are most prevalent in north America, particularly in the wetlands of Florida.

PHOTO: PETER LILEY, ALAMY ILLUSTRATOR: DEM ILLUSTRATION

WHO'S IN THE NEWS?

James Franson

Professor of Physics at the University of Maryland, USA

What did he say?
The speed of light may be slower than currently thought.

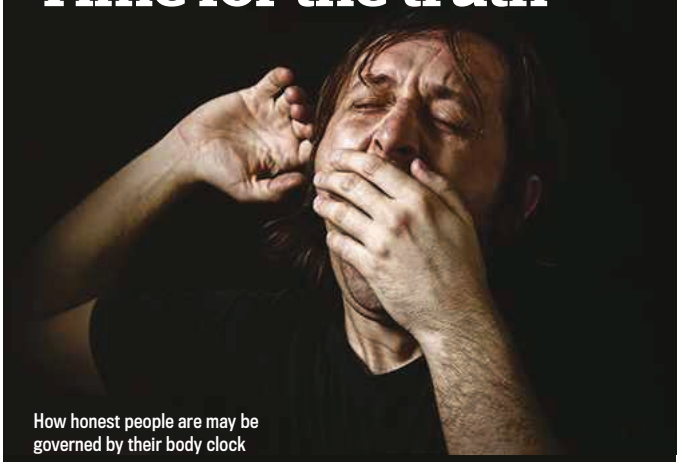
Woah there... that sounds like a bold claim?
It is. When, by international agreement, the speed of light in a vacuum was determined in 1983 to be 299,792,458m/s, it was largely assumed to be definitive. However, Franson argues that light moving through space may be slowed by 'vacuum polarisation'.

Vacuum what?
As photons – particles of light – travel through space there is a slight chance that any given photon will split into an electron-positron pair. These pairs exist for a brief period before recombining to create another photon. Franson believes this process could slow the photons down.

What if he is right?
As the speed of light is used in cosmological calculations, many measurements taken over the last 30 years could be wrong. However, Franson's paper is yet to go through the peer review process.

PSYCHOLOGY

Time for the truth



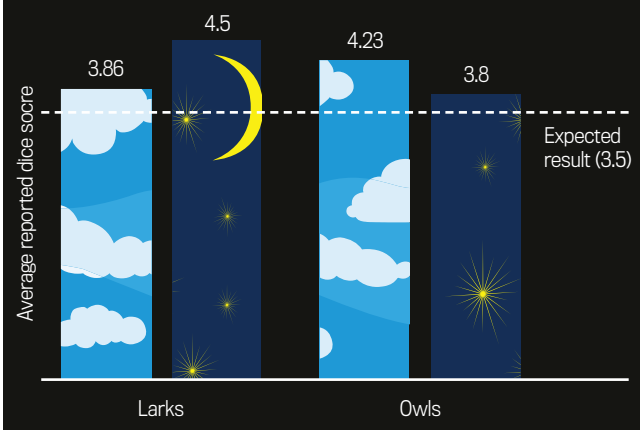
How honest people are may be governed by their body clock

EARLY TO BED, early to rise, makes a man healthy, wealthy and wise, so the saying goes. However, it seems 'morning people' may become less ethical as the day goes on.

Researchers gathered together a number of early risers, or 'larks', and a number of 'night owls', who are prone to staying up late at night. They randomly assigned them to experimental sessions from 7 to 8.30am or from midnight to 1.30am and tested their honesty by asking each participant to roll a die without the researchers seeing, and report back the number. A small amount of money was given to each participant, with higher rolls receiving a higher payout.

According to the laws of probability, the scores should have averaged out to 3.5 (1+2+3+4+5+6, divided by 6). However, larks in the night session reported getting higher rolls (4.55) than larks in the morning sessions (3.86), while owls in the morning session reported higher rolls (4.23) than owls in the night sessions (3.80).

"We assume that good people typically do good things, and bad people do bad things," says the study's lead author, Christopher M Barnes from the Foster School of Business, Seattle, "but there is mounting evidence that 'good' people can be unethical and 'bad' people can be ethical, depending on the pressures of the moment."



Larks aren't just at their best in the morning – they're at their most honest, too

PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world

The self-balancing bike

FOR SOME CHILDREN, learning to ride a bike is as easy as their ABCs. But for those who struggle with stabilisers, there'll soon be another option: the Jyrobike.

At first glance, the world's first auto-balancing bike looks just like any other child's bicycle, but as the rider starts to lean over, the Jyrobike provides a force in the opposite direction to keep them upright.

The Jyrobike's secret is a flywheel inside the bike's front wheel that spins at up to 1,550 rpm. This acts like a gyroscope, using an effect called 'gyroscopic precession' to resist any tilt applied to the wheel. The result is a bicycle that appears to defy gravity. The flywheel has adjustable settings, meaning that the balance assistance can gradually be turned down as a child's cycling skills improve.

If the makers are to be believed, this should turn a wobble-wheeled wally into a perfect pedaller in the space of an afternoon.

Patent application number: GB 1407932.1

A button for every occasion

EVERY GOOD NUCLEAR war movie features a big red button. Perhaps taking inspiration from this, the 'bttn' is a big, red, WiFi-connected button for the internet age that can be programmed to do just about anything you want, short of dispatching missiles. It can be programmed to send a text to let your partner know you're home, order a pizza, or remind you to take your medicine if you haven't pressed it within a given time.

Patent pending

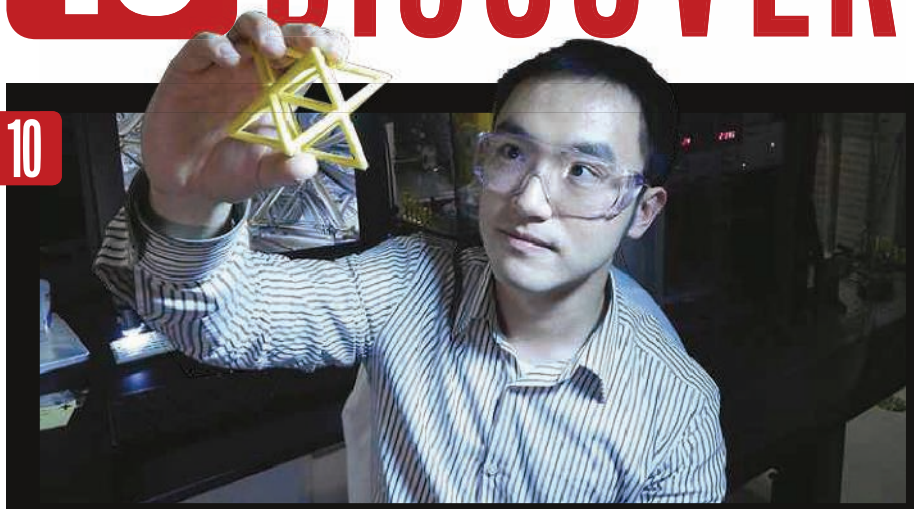
Filtering out the filth

THERE'S A LOT of pornography on the internet, but there are places where it's not welcome. In a bid to stop porn from ending up where it's not wanted, UK company Image Analyser is developing a system that detects explicit content automatically. Rather than looking for keywords, the algorithm analyses video frames, checking for curves or skin tones that suggest anything too risqué.

Patent application number: GB 2508772

10 DISCOVERIES THAT

10 Get an Eiffel of this

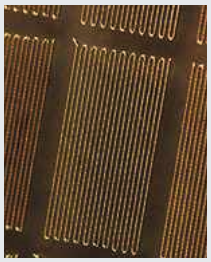


The Eiffel Tower has inspired the structure a high-strength nanomaterial

IT'S A WORLD-FAMOUS landmark, and now the Eiffel Tower has inspired a team at the Massachusetts Institute of Technology to create a new ultra-stiff, ultra-light nanomaterial. The polymer-based material, with a microlattice structure similar to that of the famous tower, has been produced by a high-precision 3D printing process. It can withstand loads greater than 160,000 times its own weight. It could be used anywhere there's a need for a material with high strength and low weight – including, possibly, in space.

9 Soft machines

RESEARCHERS AT PURDUE University, Indiana have created flexible, stretchable circuits using an innovative 3D printing technique. The material was made by embedding liquid-metal alloy sensors into a rubber-like polymer called polydimethylsiloxane. So far the technology has been used in a strain gauge, but the team say it could be used to create robots with sensory skin, as well as stretchable clothing that can interact with computers.



Flexible circuits could be useful in robotics

8 A helping hand

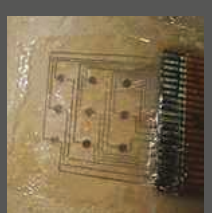
Ian Burkhart moves his hand thanks to the new technology

A CHIP THAT may help restore movement to those affected by brain and spinal cord injuries has enabled a paralysed man to move his hand and fingers for the first time in four years.

A team at Ohio State University implanted the pea-sized chip into the motor cortex of 23-year-old quadriplegic Ian Burkhart's brain. The chip interprets brain signals that are then processed by a computer and sent to an electrode sleeve that stimulates the muscles relevant to the desired movement.

7 Wear your heart on your sleeve

SOMETIMES WE HUMANS can be pretty poor at reading the emotions of those around us. But help may be on the way. A team from Daejeon, South Korea, has developed a sensor that can be built into clothing, which detects fluctuations in electrical capacitance to spot changes in the size of goose bumps triggered by the wearer's emotions.

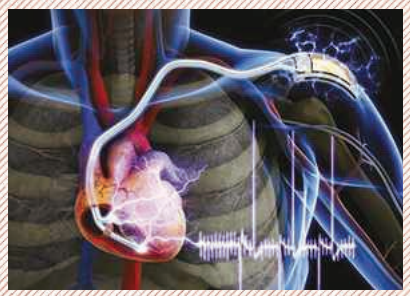


This sensor is designed to detect your emotions

The material from which the device is made may eventually be used as a real-time indicator of emotional states, say the researchers.

6 Keeping up the pace

THE BATTERY LIFE of a pacemaker can be as short as five years, but now researchers in Korea have developed a device that can harness energy from the body's movements. The flexible piezoelectric nanogenerator could prolong the life of pacemakers and provide real-time heart monitoring.



Longer pacemaker life would mean fewer operations

PHOTO: JULIE RUSSELL/LLNL, REBECCA KRAMER/PURDUE UNIVERSITY, MIT, TEL AVIV UNIVERSITY, OPTICS EXPRESS, UCL, KAIST, YOUNG-HO CHO/KAIST, OHIO STATE UNIVERSITY WEXNER MEDICAL CENTER

WILL SHAPE THE FUTURE

5 Eye-spy


The new chemical iris

THE TRADITIONAL SYSTEM of using overlapping blades to control the amount of light reaching a camera's sensor has reached a physical limit: it can't get any smaller. But now a team at the University of Kaiserslautern has created a micro-iris that could give rise to a new generation of tiny cameras for use in smartphones and tablets.

The device is just 55 micrometres thick and features rings of chemicals that become opaque when a small voltage is applied.

4 A sleeve for speed

EVER WISHED YOUR car would go faster? How about coating it in a shape-shifting, aerodynamic skin? US scientists have invented a material with a stiff skin and soft interior that allows its shape to be changed in real time. The surface can be made to dimple like a golf ball to reduce drag. It could be used in everything from sports clothing and car exteriors to radio antennae.


The dimples that make golf balls less susceptible to drag could be coming to cars

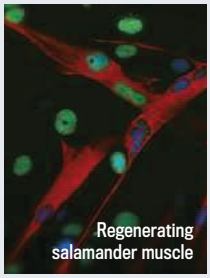
3 Nothing to sniff at

LUNG CANCER HAS one of the highest mortality rates of all cancers because it's so hard to detect. Enter the NaNose, a breathalyser that can sniff out lung cancer. Tumours produce 'volatile organic compounds' (VOCs) and NaNose uses nanotechnology to detect VOCs in the breath. In tests, it differentiated between malignant and benign lesions four times out of five.

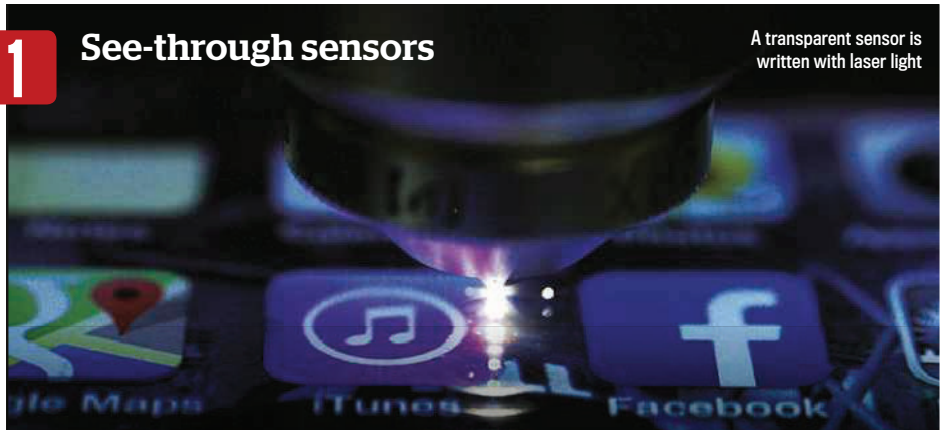

The NaNose in action

2 Grow your own limbs

SALAMANDERS HAVE AN advantage over most species: they can regrow lost or damaged organs and limbs. Now, a team at University College London has found salamanders can only do this when the ERK pathway, a mechanism that allows proteins to send signals from surface of a cell to its nucleus, is active. This pathway is never fully active in mammals, but a deeper understanding of the salamander's healing system could lead to new therapies and treatments.


Regenerating salamander muscle

1 See-through sensors


A transparent sensor is written with laser light

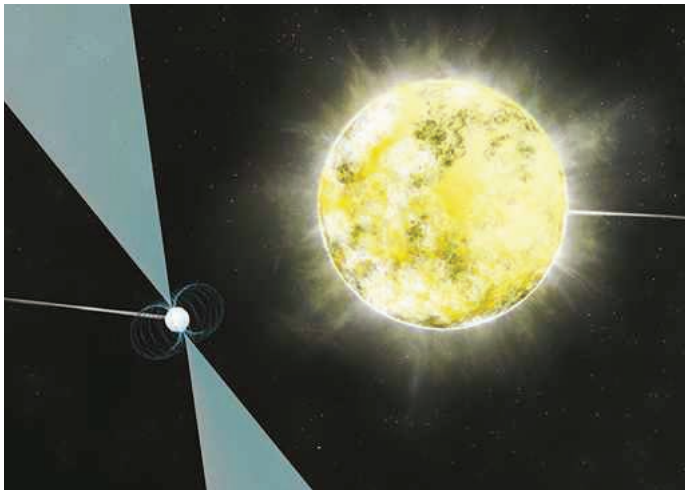
JUST WHEN YOU thought it was impossible to pack any more features into a smartphone, along come transparent sensors that can measure blood sugar levels, take your temperature and even analyse DNA.

Researchers in Montreal have developed a laser-writing technique that can be used to embed layers of sensors into glass. The technique could be used to put biomedical sensors into smartphone screens or even to create large tabletop touchscreens like those seen in movies such as *Iron Man*.

The team is currently looking for an industry partner and say that the technology could be on the market in as little as one year.

ASTRONOMY

Like a diamond in the sky...



An artist's impression of the newly discovered white dwarf (right) in orbit around a pulsar

FORGET KIM KARDASHIAN'S wedding ring – if you want to catch a glimpse of a seriously huge rock, just look to the sky.

Astronomers have identified what may be the coldest, faintest white dwarf star ever detected. White dwarfs are extremely dense, end-state stars that have collapsed to form a body approximately the size of Earth. This particular one is so cold that its carbon core has crystallised to form a diamond.

"This is a really remarkable object," says David Kaplan, an assistant professor of astrophysics at the University of Wisconsin-Milwaukee, who led the discovery. "These things should be out there, but because they are so dim they are very hard to detect."

Composed mostly of carbon and oxygen, white dwarfs slowly cool and fade over billions of years. This white dwarf is around same age as the Milky Way – approximately 11 billion years old. It has cooled to such a degree that it's very difficult to spot, but was found in mutual orbit with a larger pulsar called PSR J2222-0137. A pulsar consists of the rapidly spinning, superdense remains of a massive star that has exploded as a supernova.

The two bodies lie nearly 900 light-years from Earth, in the direction of the constellation of Aquarius. The white dwarf is estimated to have a temperature of around 3,000 Kelvin, some 5,000 times cooler than the Sun's core.

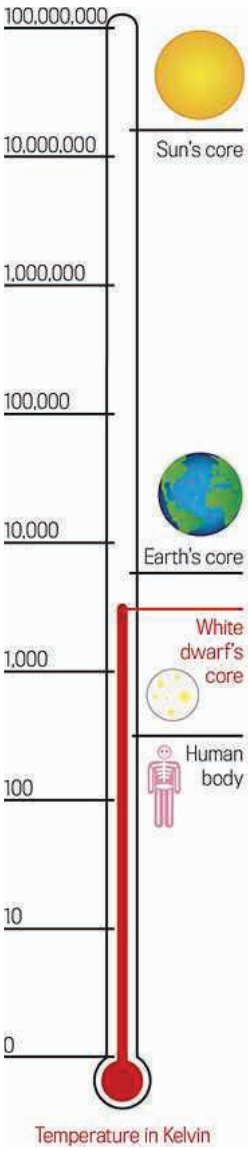


PHOTO: NRAO/AUI/NSF

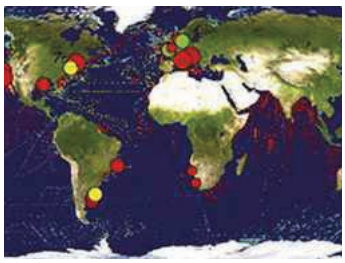
CLICK HERE

New websites, blogs and podcasts

SUPER PLANET CRASH

stefanom.org/spc

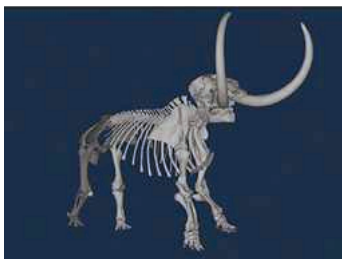
Super Planet Crash is a planetary system builder. You can choose a template, like the weird HD 80606 real-life system that has a super-Jupiter in a lopsided orbit around its star, but it's most fun to have a go at building one yourself. Add as many Earths, super Earths, ice giants and even dwarf stars as you like, then watch as gravity wreaks havoc.



JELLYFISH DATABASE INITIATIVE

people.uncw.edu/condonr/JeDI

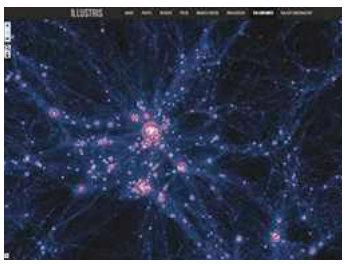
An international study sparked the creation of this database. Through the project, scientists discovered that jellies exist in all our oceans, but tend to gather at mid-latitudes in the Northern Hemisphere. This site is a bit heavy on the science side, but offers a fascinating glimpse into how researchers in this field work.



ONLINE REPOSITORY OF FOSSILS

umorf.ummp.lsa.umich.edu/wp

When University of Michigan researchers began digitally scanning the bones of prehistoric creatures over 20 years ago, the technology to share the fossils with other palaeontologists and the public didn't exist. But now it does, letting you see and manipulate 3D fossil models yourself. The detail on the individual pieces is brilliant.



ILLUSTRIS

illustris-project.org/explorer

Cosmologists use models to figure out how the Universe works. This is one of the most complete simulations of how the Universe evolved over the last 13.7 billion years, and now you can explore it at your leisure. The first galaxies formed around clumps of invisible 'dark matter', and scientists can use this model to test theories about dark matter and what makes the Universe tick.

KELLY OAKES is a science journalist who tweets from @kahoakes

INSIDE SCIENCE

ROBERT MATTHEWS

The recent announcement of gravitational waves has revealed science's ugly side

HUGE EGOS, BITTER rivalries, verbal attacks, threats of violence. Yes, you have to be tough to survive at the cutting edge of physics. Just ask those researchers who recently claimed to have evidence for cosmic gravitational waves – roughly speaking, ripples in the fabric of space-time triggered by the Big Bang itself – which have never been directly observed before.

Unsurprisingly, their claim made headlines around the world. Some of the world's top scientists hailed the results as 'astounding' and 'tremendously exciting'. Stephen Hawking even insisted the discovery meant he'd won a bet with another cosmologist, whose theory had now been shown to be wrong.

But it looks like Prof Hawking may have been a bit too keen to get his money. That's because the original claim is now being seen as premature at best, and possibly just flat wrong. Other researchers are insisting the announcement was based on assumptions that no longer look reliable. As a result, what appeared to be the hallmark of gravitational waves may be nothing more exciting than the effect of galactic dust.

The truth of the matter will begin to emerge later this year, with the release of new data from an orbiting observatory called Planck. But if it does turn out that the original claim was wrong, I for one will feel sorry for the researchers, led by John Kovac at Harvard. They spent over a year checking and rechecking their results, to avoid being accused of putting out half-baked research just to bag priority. If you think that's just being professional, check out the number of retractions appearing in top journals these days; clearly, not everyone is so scrupulous.

If some scientists had it their way we'd bring back the stockades

"Giving talks at rival institutions can be like entering a bear-pit, complete with jeers and heckling"

The decision of Harvard to hold a press conference before the results had been checked and published in a refereed journal has clearly annoyed some. But given that Nobel prizes could be in the offing, it's hardly surprising that the university wanted to put on a show. The researchers themselves have shown an impressive commitment to 'doing the right thing' despite the risk of being scooped by one of the dozen or so other teams vying to make the discovery.

But now all that seems to have been forgotten as other researchers queue up to stick the boot in. *Nature* carried a comment piece by one leading cosmologist that dismissed the original claim as a 'blunder', which seems a bit over the top. As it stands, no one knows if dust really is the best explanation. If fresh data show it is, then fine – that's science for you. But it doesn't mean the previous work was just a 'blunder'.

Oddly, the *Nature* article failed to make clear that the author is a leading advocate of the cosmic theory that Hawking bet against – and which will be dead in the water if gravitational waves really have been discovered.

But no matter; this is all good sport in the arena of cosmic physics – which is no place for wusses. Giving talks at rival institutions can be like entering a bear-pit, complete with jeers and heckling. I know of researchers who have been brought to tears or made physically ill by the verbal attacks of other 'seekers after truth'. At one notorious conference at MIT some years ago, two speakers had to be stopped from coming to blows by the chairman. Funnily enough, their dispute was over the supposed discovery of... gravitational waves.

According to Hawking, the ultimate aim of cosmic physics is to "Know the mind of God". Maybe it is, but that shouldn't involve crucifying fellow seekers after truth. ■

ROBERT MATTHEWS is Visiting Reader in Science at Aston University, Birmingham

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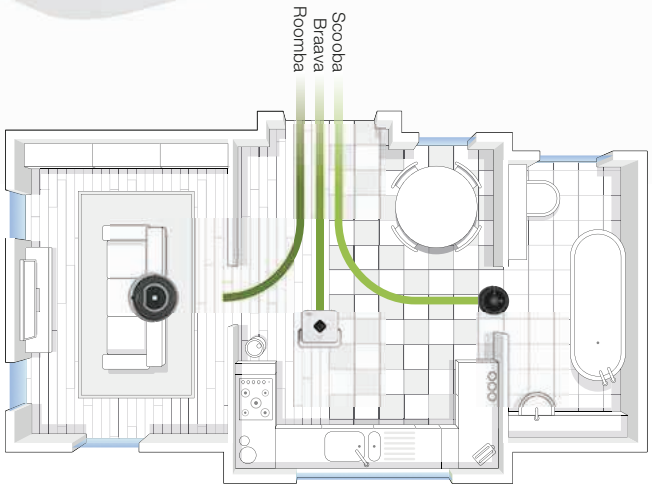

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EVERYDAY SCIENCE

HELEN CZERSKI

The ancient art of glassblowing requires mastering the atomic world

GLASSBLOWERS ARE LIKE wizards. Their raw material, sand, is opaque, gritty and mundane. But add the right ingredients, cast the right thermal spells, and sparkling, smooth, curvaceous beauty emerges. Last week, I went along to see my university's glassblower at work, and I was reminded of this magical world. Stepping across the threshold was like stepping back in time. It was a grotto of weirdly tapered glass pipes, bulbous vessels and mysteriously-shaped tongs, with orange flames flickering among it all. I've always been fascinated by the transformations this environment hosts. What I love most of all is how unlike any other craft this is. A glassblower has one tool to coax atoms into shape: temperature. Get that right, and the world is your glass oyster.

Imagine a glassblower in 1850. He knows nothing of atoms and thermodynamics, but makes a living by controlling the atomic world. In sand, silicon and oxygen atoms are locked together in a rigid regular lattice. But put the sand in a furnace and heat it to about 1,475°C, and those atoms become mobile. They are still linked together, but more randomly. Molten glass radiates heat energy as red light, so the melt glows. The glassblower lifts out a large blob of these restless silicon and oxygen atoms, and they're linked together so strongly that they don't drip off the blowpipe. When he blows air into the blob, the air pushes the glass outwards.

Cooler melt is more viscous and flows more slowly, so the colder skins on the inside and outside of the blob act like a container for the hotter contents, and the glassblower might dip it in water to cool it further. The surface is smooth due to surface tension. The glassblower constantly spins the blowpipe, using gravity to even out the glass. Then he transfers the large glass bubble to another rod, called a punty. It might need heating again, to maintain the balance between having a cool skin, and keeping the centre hot enough to flow.

"Imagine a glassblower in 1850. He knows nothing of atoms, but makes a living by controlling the atomic world"

Now he spins the bubble rapidly so that centrifugal forces take over. The atoms flow outward, and a flat disc is formed. Glass becomes very viscous as it cools, so as the disc gives off its energy to the surroundings, the atoms are too sluggish to slot back into their crystal structure. They're stuck in the same positions they were in the liquid.

Now that the melt has cooled, it's not glowing red any more, and the glassblower can see his furnace through it. Just before the glass solidifies fully, the glassblower disconnects the punty, leaving a bullseye shape in the middle. This is what you see in old pub windows – it's the signature of crown glass (plate glass made by this process). The outer disc would have been cut into small panes, to be joined together using lead. Although the atoms have the structure of a liquid, they're not still flowing in any practical sense – it would take longer than the age of the Universe for a glass window to become a puddle. The reason old windows are thicker at the bottom is that they were put in that way round to help the rain run off.

There is huge skill involved in glassblowing. But at its core, it's just a way of shifting silicon and oxygen atoms around without touching them, using temperature to give you precise control over their flow speed. This atomic wizardry helped build the modern world. And I love that there are some places, like the university glassblower's workshop, where that skill is still shaping the experiments of tomorrow. ■

DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter who appears regularly on *Dara O Briain's Science Club*

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INTO THE FUTURE

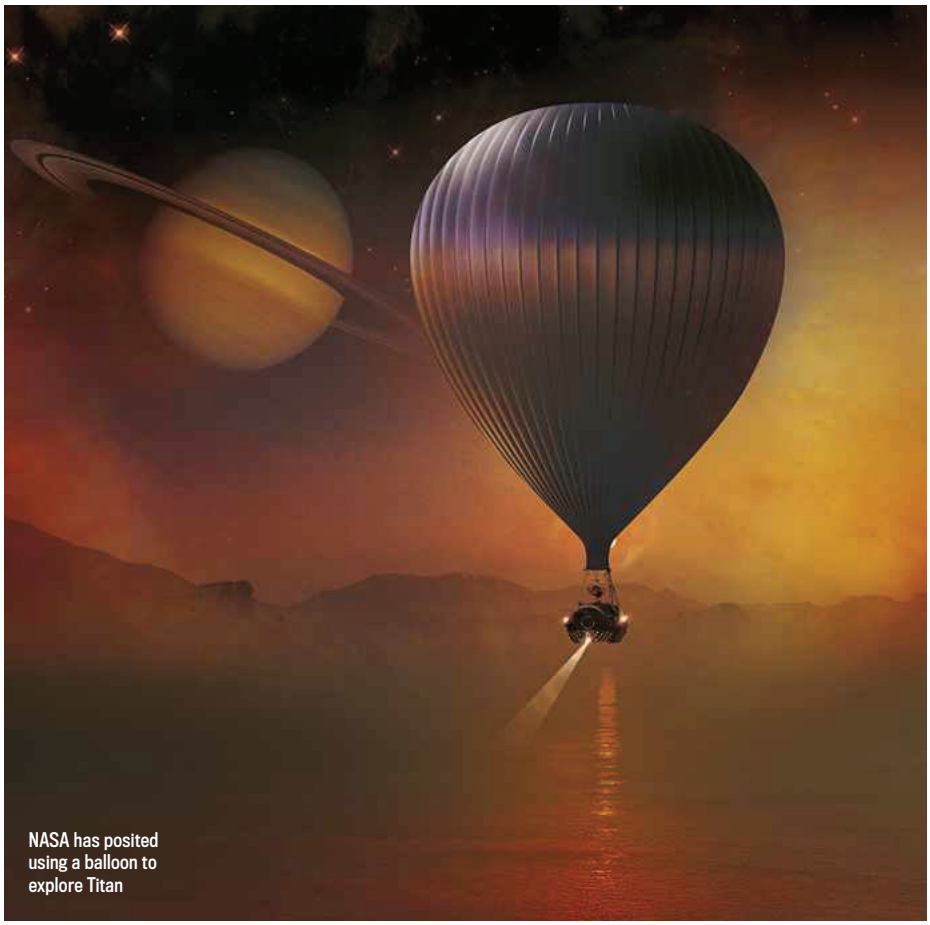
STEPHEN BAXTER

Using balloons to explore the Solar System is no longer just hot air

THE HOME OF *Focus*, the city of Bristol hosts the world-famous International Balloon Fiesta in August. Balloons have a long and proud history as the oldest successful human-carrying flight technology. While 'Chinese lanterns', used as decoration and for message-sending, date back to the 3rd Century AD in China, it was in 1783 that the Montgolfier brothers made the first tethered ascent in a hot-air balloon, from Paris, followed shortly by untethered ascents.

Balloons work on the principle of buoyancy. The hot air in the Montgolfiers' envelope was less dense than the air around it, so naturally rose up, carrying with it the weight of the envelope and the gondola with its passengers. Another way to achieve such buoyancy is to use a gas that's less dense than the atmosphere, such as hydrogen or helium – and indeed the first human-carrying hydrogen balloon flight was also made in 1783. Ballooning captured the popular imagination. Jules Verne's first novel of a fantastic journey was *Five Weeks In A Balloon* (1863), about a daring crossing of a still-unexplored Africa.

Today, balloons continue to push the boundaries of exploration. Felix Baumgartner famously set a new altitude record of 39km (24 miles) for a manned balloon flight in October 2012. The record for unmanned balloons, at 53km (32 miles), was set in May 2002 by a balloon launched from Japan. This is higher than any conventional aircraft can fly – only rockets and rocket planes have been higher.



NASA has posited using a balloon to explore Titan

And balloons may be used in the more remarkable explorations of the future. In 1985, the Soviet Union's Vega 1 and Vega 2 probes deployed balloons in the atmosphere of Venus, defying ferocious conditions of heat, pressure and acidic corrosion. Hovering at around 50km (31 miles) up, one balloon failed, but the second lasted for nearly two days.

"Balloons have been proposed to explore Saturn's moon Titan, using an argon-filled envelope"

Agencies such as NASA continue to explore ballooning concepts for space missions. The advantages of balloons are their lightness and relative cheapness, and their ability to deliver an intermediate view of a planet, between the capabilities of an orbiter and a surface rover. A balloon over Mars would be 100 times closer to surface features than an orbiter, and so could deliver comparatively close-up studies, and it would cover thousands of times as much terrain as a rover. A balloon could even be made to drop periodically to the surface for samples. And of course, a balloon is ideally suited to study the composition of the atmosphere.

On the other hand, the technology does set challenges. The insertion into the target planet's atmosphere is tricky, with an entry behind a heat shield, and the balloon then extracted by a parachute and inflated in mid-air. And with long time delays for commands from Earth, the balloon needs some autonomous intelligence to achieve its mission.

Though NASA has yet to fly a balloon mission, its Jet Propulsion Laboratory has tested the technology, such as envelope materials that could withstand Venus's acidic clouds. Balloons have been proposed to explore Saturn's moon Titan, using an argon-filled envelope in an atmosphere that is mainly composed of nitrogen. Even the upper hydrogen-helium atmospheres of the gas giants could be explored, including mighty Jupiter. Arthur C Clarke's thrilling *A Meeting With Medusa* (1971) depicted a manned descent into Jupiter's cloud layers. But "only one kind of balloon will work in an atmosphere of hydrogen, which is the lightest of all gases – and that is a hot-hydrogen balloon". One day we'll explore the most challenging of worlds with hot air balloons – our earliest flight technology. ■

STEPHEN BAXTER is a science fiction writer whose books include *The Science Of Avatar* and the *Northland* series

ILLUSTRATOR: ANDY POTTS

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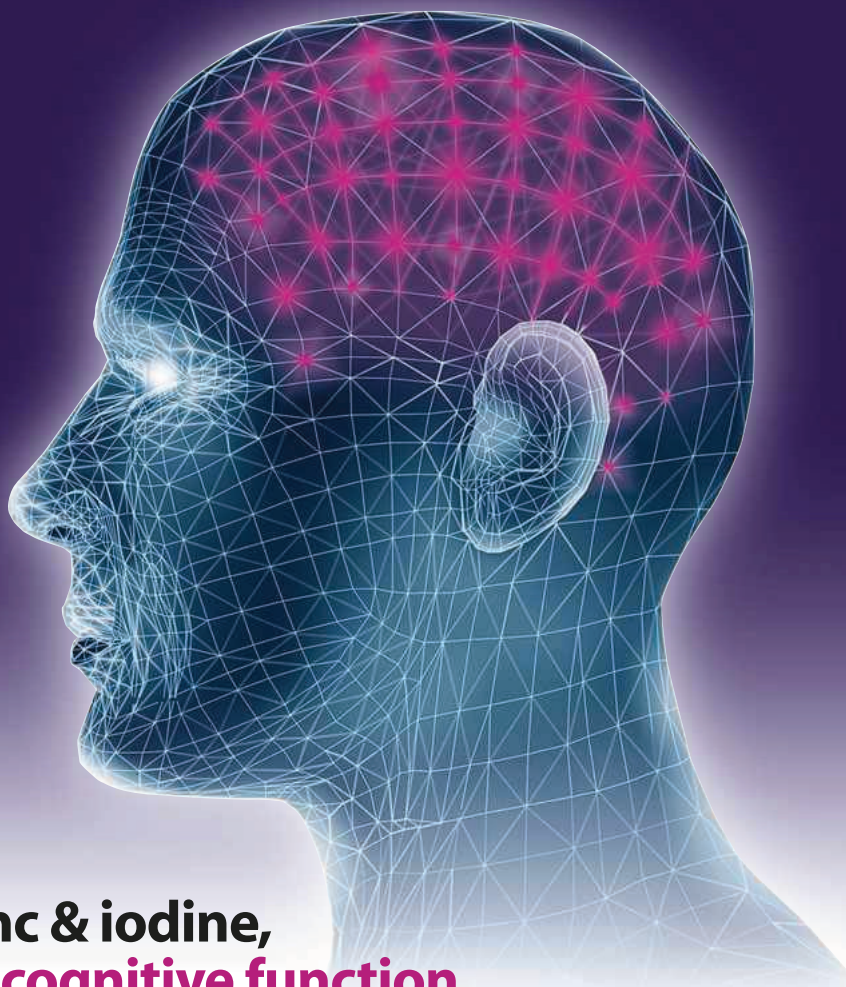

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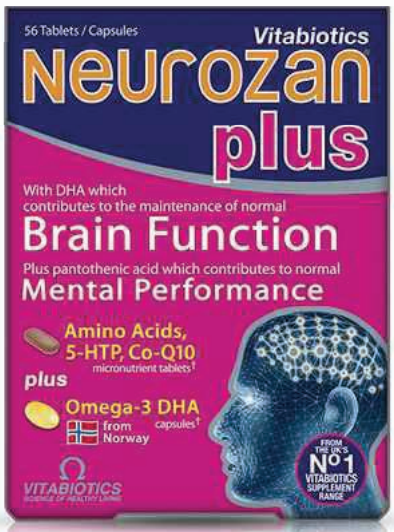

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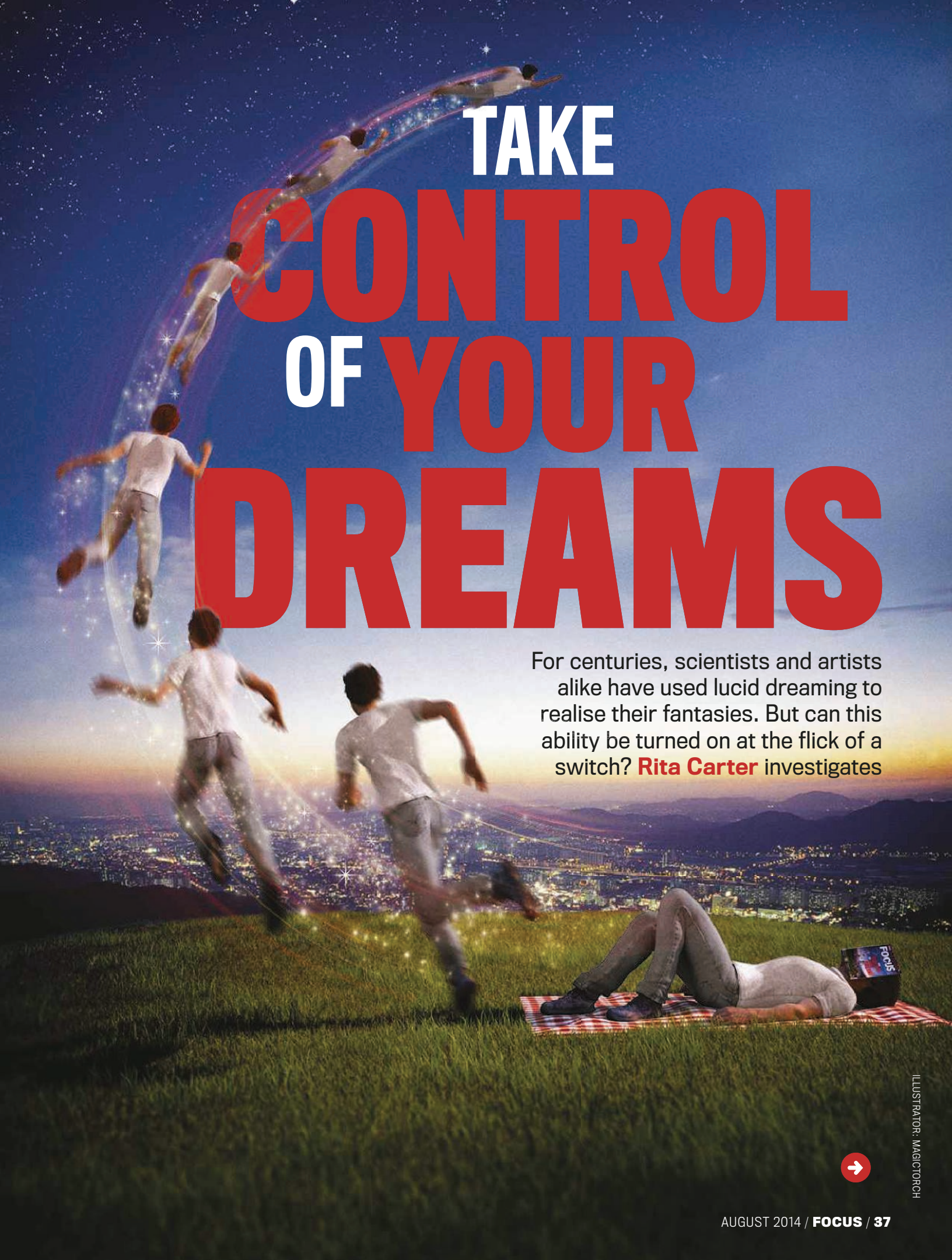
TAKE CONTROL OF YOUR DREAMS

For centuries, scientists and artists alike have used lucid dreaming to realise their fantasies. But can this ability be turned on at the flick of a switch? **Rita Carter** investigates



ILLUSTRATOR: MAGICTORCH

LAST NIGHT I flew low over Rio, talked to a long-dead friend and turned a chimney pot into Stonehenge. You probably did something similarly bizarre, though you probably don't remember. Dreams are like that – weird stuff just happens, and then evaporates. In my case, though, the events in my dream were consciously willed, and today my memory of them is crystal clear. Because this was no ordinary dream: it was lucid.

Lucid dreaming is a strange state of consciousness which combines the vivid perceptions and bizarre events that characterise normal dreaming with full awareness and control. It happens when parts of your brain that are normally dormant during dreaming become active,

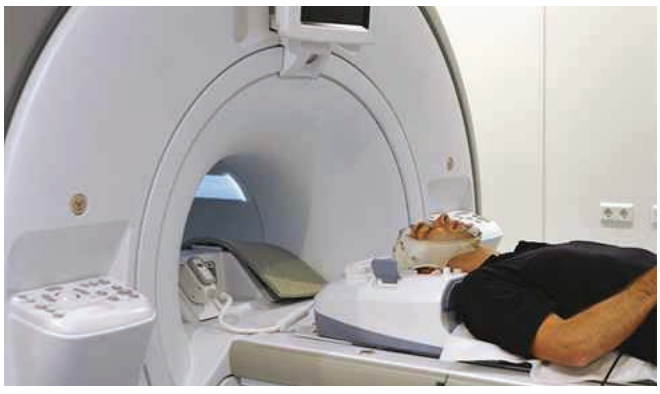
"Lucidity has often been mistaken for a spiritual or supernatural phenomenon"

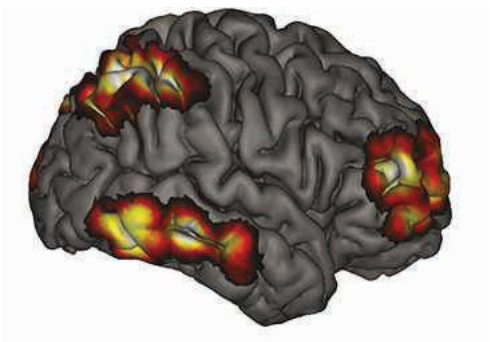
jettisoning you into a hybrid state of wake and sleep. The dream goes on, but now you know who you are, where you are, and that what you are seeing and hearing is a hallucination. Instead of just lying back and enjoying (or enduring) the dream, you can control the action like a film director equipped with immersive CGI.

Want to meet the Pope? Bring him on. Fancy dropping in at the White House? Give it a second or two and there you are in the Oval Office. Turn your mother into a skunk? Look away from her for a second, then look back... and hold your nose. You can do anything and everything your imagination encompasses.

SCIENTIFIC STUDIES

Lucid dreams are often mistaken for a spiritual or supernatural phenomenon, but recent brain-imaging studies show that they are powered by physiology. In 2012, researchers led by Martin Dresler and Renata Wehre at the Max Planck Institute of Psychiatry in Munich recruited a





Clockwise from top: transcranial stimulation; a group session at the Lucidity Institute; the brain regions that are more active during lucid dreaming; a patient undergoes an MRI scan to study the brain when dreaming

PHOTO: PRESS ASSOCIATION, MAX PLANCK INSTITUTE OF PSYCHIATRY X2, YOUCANLUCIDDREAM.COM

LUCID VS ORDINARY DREAMING

The neurophysiological differences between the two dream states explained

IN DEEP SLEEP practically all our brain systems are turned right down, with neurones firing at <4Hz (delta waves) rather than the 8–40+Hz (alpha, beta and gamma waves) that are typical of waking activity.

Normal dreaming is marked by extended flurries of fast firing in the areas that generate sensations. These produce vivid sights and sounds of dreams. Most of the prefrontal cortex stays effectively offline, however, so our thoughts are uncritical and weird.

Lucid dreaming occurs when, in the dreaming state, more parts of our brain come back online. These activated areas bring back our self-knowledge, restore our critical faculties and give us back the ability to direct our imagination, and hence the content of our dreams.

The brain areas that control movement and receive input from the sense organs remain dormant, though, so we are still in a state sleep paralysis and unaware of the outside world while dreaming lucidly.

habitual lucid dreamer to sleep in an fMRI scanner. The participant informed the researchers when they became lucid by means of an eye signal (the eyes are the only part of the body that people can move freely while they are asleep, and the movement can be detected beneath the lids) and the scanner then recorded the sleeper's brain activity. It showed a significant increase in electrical activity in several areas of the brain, most notably the precuneus, a region associated with the sense of agency and self-reflection.

Some people experience lucidity spontaneously, but to do it at will usually takes lengthy self-training. Hence there has been great excitement recently at the publication of a study that suggests it could be triggered by a nifty electrical device.

Professor Ursula Voss and a team at the University Medical Centre in Göttingen, Germany monitored the brainwaves of 27 non-lucid dreamers as they slept. When the EEG readings showed them entering Rapid Eye Movement (REM) sleep – the state in which vivid dreams occur – the researchers sent a short burst of AC electricity through their brains.

A HELPING HAND

The technique Voss's team used is known as transcranial Alternating Current Stimulation (tACS). It involves placing sponge electrodes on the scalp and sending a minute alternating current (in this case, 250 microamps) through the skull and into the brain. The stimulation was aimed at the areas which 'woke up' in the earlier fMRI study, and various oscillation rates were used, from less than 1Hz (once a second) up to 40Hz, the firing rate of neurones generating bright consciousness.

The results showed that stimulation at the beta and low gamma frequencies (25-40Hz) produced EEG alterations, which in some cases seemed to affect dream consciousness. One participant recalled talking to a famous actor and then thinking: 'Oops, you are dreaming!'

Although recognising that you're dreaming is a hallmark of lucidity, a single brief flash of insight does not make a dream lucid, says psychologist Stephen LaBerge. LaBerge is the founder of the Lucidity Institute, which has produced by far the greatest body of research into the subject over some 30 years.

"The passing thought, 'Oh, this is a dream' is only a minimalist example of lucid dreaming, and not enough to qualify by our definition," he says. "These researchers assumed lucidity when the subjects reported dissociation in their dreams – things like being a different person or seeing yourself from outside – which is an entirely different thing and a very unusual feature for lucid dreams." LaBerge experimented with brain stimulation himself in the early '90s, but abandoned it after concluding it had no significant effects.

More recently, Tadas Stumbrys and colleagues at Heidelberg University used transcranial Direct Current Stimulation (tDCS) on 19 sleeping volunteers who already described themselves as frequent lucid dreamers. They reported a slight enhancement of lucidity, but the researchers rated the effects as weak.

HOW TO HAVE LUCID DREAMS

Six steps you can take to start lucid dreaming yourself

1 Keep a dream diary

Record your ordinary dreams when you wake up and note key features (dream signs) such as morphing objects or strange landscapes. Recall their shape, colour and texture. This will help you recognise them and think 'this is a dream'.

2 Prepare your mind

Deliberately visualise your dream signs throughout the day. Pay special attention to their sensory aspects: colour, texture, shape and size. Try and make them as 'concrete' as possible.

3 Determine a personal dream sign

Imagine, for instance, a floating cat or blue grass, and think of it often. Associate it with something real – for example, your own cat or the grass in your local park. This will encourage it to pop up in a dream and prompt recognition.

4 Reality check

Make it a habit to check your watch frequently and then check back a few seconds later. If the time has changed, or it looks weird, you are probably dreaming. Try to hold that thought and grab the chance to become lucid.

5 Take a nap

Wake up an hour or so earlier than usual, spend half an hour reading and thinking about lucid dreaming, visualise your dream signs repeatedly, then go back to sleep with the intention of becoming lucid.

6 Cholinergic supplements

The neurotransmitter acetylcholine helps keep neurones firing, which is said to increase the frequency and intensity of lucid dreams. Galantamine is a legal smart drug that prevents acetylcholine breakdown in the brain. Consult with your doctor before using and start with a low dose (<4mg for few nights only).

Nevertheless, in theory, brain stimulation should help to trigger lucid dreaming, and the stimulation experiments may mark the start of a new era in which brain stimulation devices make lucid dreaming easier and more commonplace.

STIMULATE YOUR MIND

Brain stimulators have a vast range of potential uses, from serious medical applications through to pepping up your gaming skills, but they are still difficult to buy. tACS devices are currently only available through suppliers who sell exclusively to research institutions. Voss and colleagues used a German-made machine called Neuroconn which costs upwards of £5,000.

It is, however, possible to buy transcranial Direct Current Stimulators (tDCS) for just a few hundred pounds. A company called Foc.us (no relation!), for example, produces a tDCS generator plus headset which costs £224. The makers sell it based on the claim that it can improve your online gaming skills. A somewhat plainer device is available for £179 from trans-cranial.com. They have yet been proved to induce lucid dreaming, however, and are not suitable for sleeping.

There are, though, devices designed to stimulate lucid dreaming which work on entirely different principles. One of these is the Dream:ON smartphone app, which was developed by Richard Wiseman, who is professor in the Public Understanding of Psychology at the University of Hertfordshire. The app is designed to turn on a preselected 'soundscape' when a person starts dreaming, the idea being that the sound triggers lucidity.

Wiseman and his team have gathered dream reports from hundreds of users since launching the first version of the app two years ago. These show that, although the app does not reliably bring on a lucid dream, it does help people to influence the content of their dreams. "If someone chose the nature soundscape then they were more likely to have a dream about greenery and flowers," says Wiseman. "In contrast, if they selected the beach soundscape then they were more likely to dream about the sun beating down on their skin."

The team also found that certain soundscapes produced far more pleasant

PHOTO: PRESS ASSOCIATION X2, ALAMY, THINKSTOCK

Foc.us's tDCS headset is said to improve your gaming skills – its utility as a lucid dreaming aid has yet to be proved

Dream:ON detects when you're sleeping, then attempts to nudge you into lucidity by playing sounds

dreams. "Having positive dreams helps people wake up in a good mood, and boosts their productivity," enthuses Wiseman. "We have now discovered a way of giving people sweet dreams, and this may also form the basis for a new type of therapy to help those suffering from psychological problems such as depression."

NovaDreamer is another device that's said to encourage lucid dreaming, and takes the form of a mask which you wear while you sleep. A sensor

FAMOUS LUCID DREAMERS

CHRISTOPHER NOLAN

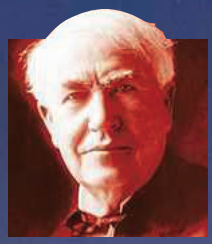
Film director Nolan took the inspiration for his 2010 thriller *Inception* from his own lucid dreams. The film follows a dream thief, a corporate spy who uses a device to invoke lucid dreaming at will to steal ideas from the minds of CEOs.

EDGAR ALLAN POE

Several of Poe's poems describe dreams, including *A Dream Within A Dream*, which talks about lucidity. In his essay *An Opinion On Dreams* he refers to them as a supernatural phenomenon, similar to the visions of the prophets.

RICHARD FEYNMAN

The physicist wrote extensively about his lucid dreams. He induced lucidity by reflecting on his thoughts as he dozed off, and checked the reality of his dream experiences by returning to things he saw in them and noting if they were the same.



THOMAS EDISON AND NIKOLA TESLA

Edison used to balance a coin on his head as he dropped off with the idea that the sound of it falling would remind him he was dreaming. Tesla was famous for intense visualisations which he used in his laboratory.

DR CELIA GREEN

Oxford researcher Green was the first person to experiment extensively with lucid dreaming. In the '60s she and some friends carried out experiments that showed lucid dreams were indeed dreams, not 'astral travelling' as many people believed at the time.

"It is unlikely that any of these devices will allow you to dream lucidly whenever you want to"

inside it detects REM sleep onset and gives a visual signal, again designed to jog you partially awake. It also has a 'reality checker'. One of the strange features of lucid dreaming is that electrical devices – especially light switches – do not function normally in such dreams. There is usually a delay after you have pressed them and the light is curiously low. Pressing the reality check light switch on the mask and seeing what happens is therefore a way of finding out whether you are dreaming or really awake.

The NovaDreamer was developed by the Lucidity Institute in the '90s and the original model is no longer made, but a new version should be available very

Professor Ursula Voss hopes her research into dreaming may benefit those who suffer from nightmares

Like the NovaDreamer, REMEE sends a signal when you're asleep to jog you into a lucid dream, but it can't determine whether you are in REM sleep or not

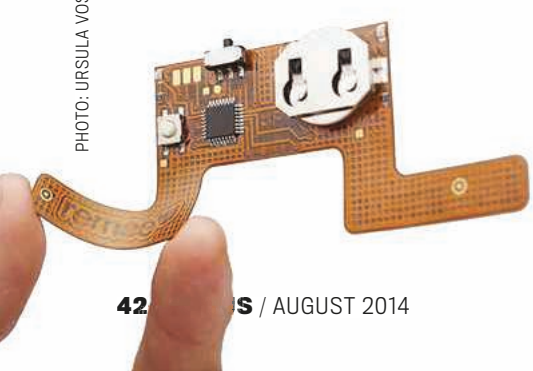


PHOTO: URSULA VOSS X3, DUNCAN MCCLOUD FRAZIER

REMEE inventors Duncan McCloud Frazier and Steve McGuigan of Bitbanger Labs

LUCID DREAM ODDITIES

As entertaining as it can be, lucid dreaming can also be a disconcerting experience for the novice

FALSE AWAKENING WITH SLEEP PARALYSIS

You feel you are awake, but paralysed or weighed down so doing anything is like moving through glue. You may think you are getting up, getting dressed and even going to work – then you 'wake up' again and realise you were dreaming. This can happen several times and may be very scary. Do a reality check and if you are dreaming, relax and try to turn it into a fully lucid dream.

'EVIL' ATMOSPHERE

Lucid dreams can be euphoric but semi-lucid states may be accompanied by a strong sense of evil, as though the atmosphere is charged with dark, scintillating vibrations. This seems to be due to activation of the amygdala – the part of the brain that alerts you to danger. The experience is by definition terrifying, but if you recognise that it is a dream you may be able to dispel it by redirecting your imagination.

SENSED PRESENCE

You may get a strong feeling that a person or 'presence' is with you, usually just out of sight. It may be hostile or benign.

OUT-OF-BODY EXPERIENCES

Can be deliberately induced during lucid dreaming, along with floating, flying, and travelling through walls. OBEs are frequently accompanied by a sense of euphoria.

SPINNING

If you are lucid and feel yourself dropping out of the state, try spinning around like a ballet dancer or ice skater. It helps keep you lucid.

CONVERSATIONS

You can conjure up anyone you like – dead or alive – in a lucid dream. Although any conversation is generated by your own brain, you have no idea what your dream people will say so these chats are just as interesting as in real life.

soon. Meanwhile, you may be able to pick up an original on eBay. The Lucidity Institute also runs training courses in lucid dreaming, including a week-long residential retreat in Hawaii.

REMEE is another mask that gives you a signal as you sleep, though it does not monitor your eye movements so you have to preset it for a given delay and hope it comes on when you are in REM sleep. Finally, two new headsets are currently soliciting investment on Kickstarter. Aurora and DreamNET both measure brainwaves as well as eye movements to check for REM before, again, sending out the sensory signal designed to nudge you into lucidity.

On their own, it is unlikely that any of these devices will allow you to dream lucidly whenever you want to. For that you almost certainly need to combine them with training (see 'How to have lucid dreams', p40). My own interlude of lucidity last night was certainly helped by dusting down and using my old NovaDreamer, but it probably only worked because I learned how to go lucid years ago and because writing this article had reignited the idea.

Aurora is one of several lucid dreaming headsets currently seeking funding on Kickstarter

HEALTH BENEFITS

Research into lucid dreaming can be justified by its potential for therapy. Paralysed and disabled people can regain conscious access – at least for the duration of the dream – to all the physical experiences they cannot have in waking life. Those with phobias can conjure up and confront the objects they fear, knowing that they can make them vanish instantly if it is becomes too frightening.

Ursula Voss hopes her team's work could one day help in providing therapy for people who suffer nightmares. They could, for instance, re-direct the action, so the monster becomes a furry kitten, and the gun that is about to shoot them becomes a flower. "It may sound far-fetched," she says, "but we hope it could be even used to help people with disorders of consciousness such as coma".

The main joy of lucid dreaming, however, is that it's fun. No two people will choose to do the same thing in their lucid dreams (although anecdotally, flying seems to be almost universally popular). But whatever it is, you can do it in the luxurious knowledge that no-one but you need ever know about it.

So dream on. ■

RITA CARTER is a medical journalist with a particular interest in consciousness and the brain, and the author of *Mapping The Mind*

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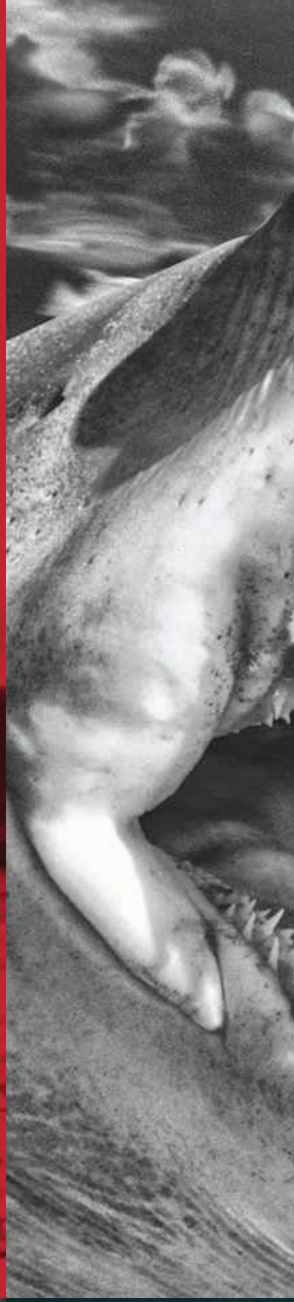


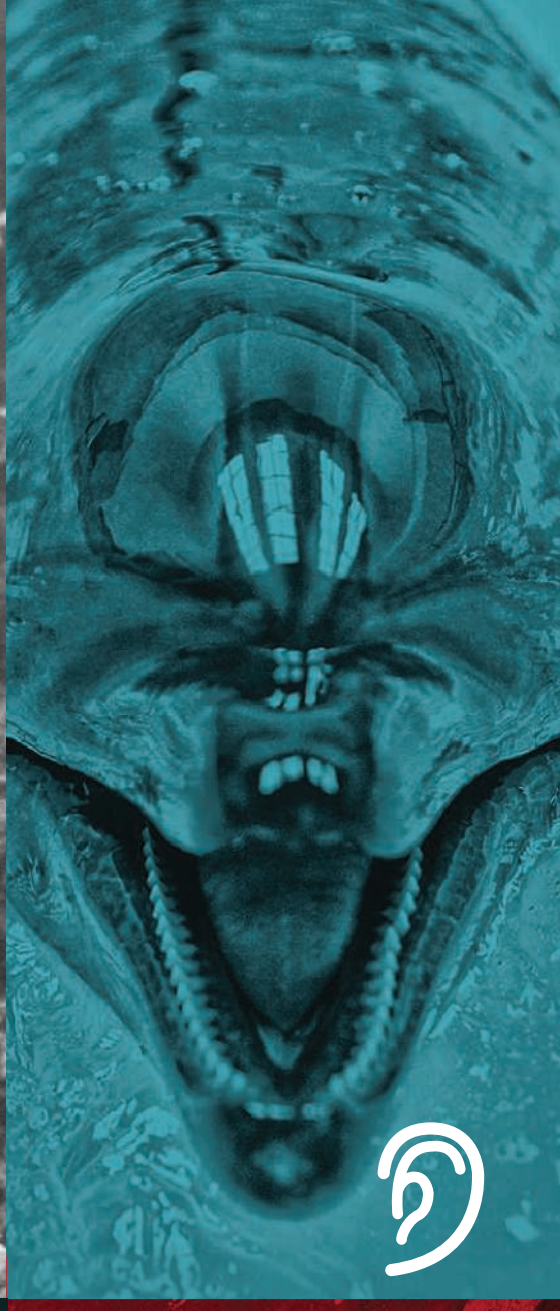
BBC TWO

Accompanies *Beyond Human*, presented by Helen Czerski, airing on BBC Two next month

ANIMAL SUPERSENSES

There are animals with keener hearing and sharper eyes than us, but as **Helen Czerski** reveals, some creatures have different sensory systems altogether

PHOTO: BBC, THINKSTOCK X3, ROBERT HARDING, GETTY



OUR BODIES ARE constantly monitoring the world, detecting nuances in light, sound, chemistry and texture. That continual rich flow of information is so important to us that taking away any of our senses can cause anxiety and depression. But we are only capable of sensing a tiny fraction of what's going on in our surroundings. Compared with some animals, we wander through life in a blissfully ignorant state, missing out entirely on signals that they rely on for survival.

Our sense organs are impressive: a range of physical detectors built into our bodies, constantly on the alert. They measure changes in our environment and convert them to nerve impulses. But you don't need an ear like ours to hear, or an eye like ours to see. There are other ways of sensing the world, and the animal kingdom is the place to see them in action.

A few months ago, I was perched on the bumper of a truck in Cuba with a snake, a Cuban boa, peacefully coiled around my arms. The scientists who study these snakes had just been enthusing about its iridescent skin, which was indeed stunningly beautiful. But I was more interested in something else. I turned the snake around so that I could see its head in profile, and both the snake's vision organs on that side of its head would have seen me.

Its left eye saw me in visible light, and the array of pits along its jaw saw me in the infrared. Each one of those heat-sensitive pits provides an image so crude it's barely an image. But the information from all of them together can build up a better picture, good enough for the snake to hunt warm-bodied bats in inky black caves. This technique is the only way to form images in low light without a lens. Humans had to develop powerful computers to do the processing before they could manage the same trick. There's a gamma-ray telescope in orbit that uses exactly this method (called a coded aperture array) to look out for distant exploding stars, because gamma rays are too powerful to be focused by lenses. But the snakes got there first.

"There are other ways of sensing the world, and the animal kingdom is the place to see them in action"

Every species has changed over time in response to a unique set of evolutionary pressures. It's not just that some species sense more of the world than we do: the way their senses work is often different. And every technique for detecting what's going on in your surroundings has its advantages and disadvantages. Ever wondered whether it would be worth having ultraviolet (UV) vision? Take a look at the birds, which can all see UV. We humans have protective filters in our eyes to prevent the damage that UV would cause, and that light never reaches our retina. But birds don't live long enough to worry about cataracts, so they get the benefit of the extra colours.

Together, the species on Earth have a vast repertoire of sensory expertise. But how do they do it? What do you have to build into your body in order to detect different aspects of your physical surroundings? Evolution has provided a way to test and develop many possibilities. But humans are only one species, and we haven't got it all. What strange senses are we missing out on?

Helen meets a Cuban boa, which is able to see in infrared, while filming *Beyond Human*

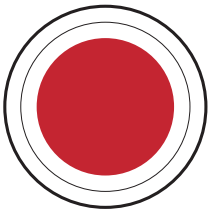
PHOTO: ARDEA, BBC

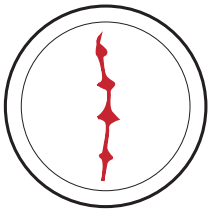
Not only can this Tokay Gecko see in UV, it can also judge distance without stereoscopic vision, thanks to a remakable adaptaion to its irises

GECKO *VISION* THE ONE-EYED WONDER

THE NOCTURNAL HELMETED gecko's eyes work on the same basic principles as ours, but with a few nifty twists. These lizards were active during daytime for a significant chunk of their evolutionary past, and with all that bright light around there was no need for sensitive rod cells, which let us see in low light. So the rod cells disappeared and the geckos are left with three types of cone cell covering their retina, for green, blue and UV light. These days, they are active at dusk, and even with wide-open eyes, they still have colour vision in dim light.

But these geckos are still out and about in bright light sometimes, and this is when their eyes show off a really unusual strategy. The gecko's pupil becomes slit-shaped in bright light, but it's also got four notches along each side. When the slit closes up, instead of having one single pupil like ours, the gecko has four in a line. Each one will form a separate image on the back of the lens – unless the object is a specific distance away, in which case all four images lie on top of each other. It's thought that the gecko uses this to judge distance. They don't have stereoscopic vision like ours, so they can't calculate distance by comparing the different images from each eye. But with those four pupils in each eye, they don't have to.





In low light the gecko's pupil dilates (above), but in bright light it closes to reveal four notches (below) that help it judge distance

HOW WE COMPARE

THE HUMAN EYE is a complex organ. Light flows in through a circular aperture called the pupil, which controls how much light reaches the back of the eye. It constricts when it's bright, so that only a thin, intense beam of light hits the retina at the back of the eye. The small region where that beam lands is called the fovea and it's full of densely packed cone cells. We have colour vision because there are three types of cones, for red, green and blue light. But when surroundings are dim, our pupils open up to allow in more light, illuminating the sea of rod cells that make up the rest of the retina. These only distinguish black and white, but they're very sensitive to low light. That's why everything looks washed-out at dusk – the light is mostly falling on rod cells, so our colour vision is poor.

PLATYPUS *ELECTRO-SENSITIVITY*

HUNTING WITH ELECTRICITY

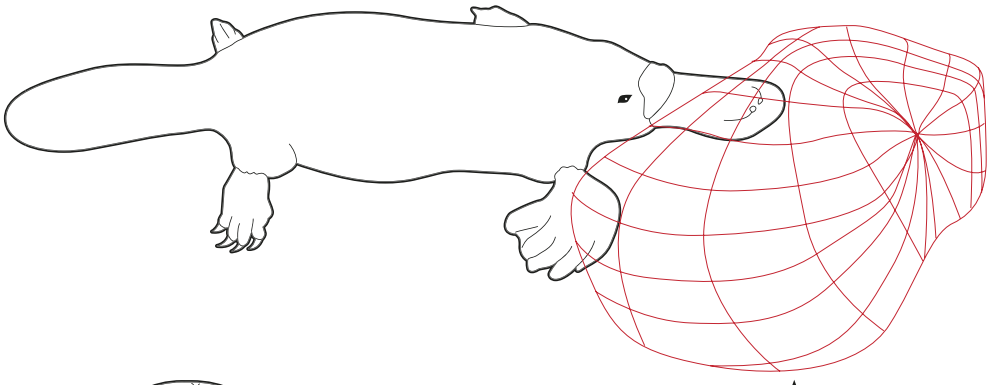
IMAGINE YOU'RE AN aquatic mammal, searching for prey buried in the mud of a stream. You close your eyes, ears and nose, dive underwater, swim down to the bottom, and then what? This is how the platypus hunts. Blind, deaf, and unable to smell anything, it pays attention to something else. Shrimp and other prey are moving around, and each bit of movement could give their position away. All muscle contractions involve electric pulses, and because water conducts electricity those pulses are broadcast out.

The secret weapon of the platypus is its beak, which is covered in mucus glands capable of sensing electric fields. Each gland has nerves and the mucus transmits the electricity to the nerves. It's a fearsome arsenal of sensors – each platypus has an estimated 40,000 electro-sensors. It's also got 60,000 touch sensors on its beak, and it uses the two systems together to search for objects in the mud and then decide whether it might be suitable for dinner.

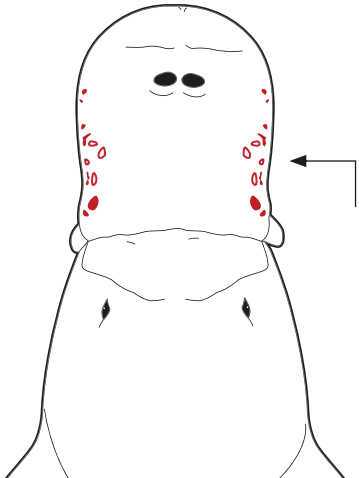
As the platypus swims along, it sweeps its bill from side to side, and it uses the changing signal from each sweep to work out the direction of the prey. Not only will they swim straight towards a shrimp, they'll quickly home in on the DC voltage from a buried battery as well. This is highly effective hunting – a platypus finds half its body weight in prey every single night.

One of the most unusual animals on the planet, the platypus hunts its prey by detecting electrical impulses

PHOTO: DAVE WATTS/NATUREPL.COM, GETTY ILLUSTRATION: ACUTE GRAPHICS



In experiments platypuses were able to detect an object set at 2Hz from roughly 30cm away. The range of the beak is shown here in red



The position of the platypus's electro-sensors can be seen here as solid red areas on the right and left of the beak; its touch receptors are shown as open rings. It's thought the animal may have 100,000 individual sensors

HOW WE COMPARE

WE LIVE IN an environment buzzing with electric fields of one sort or another, but even if we could sense them, most of the time there would be nothing to detect. That's because we live in air, which is a poor conductor of electricity. If we did have this sense, we'd rarely be able to notice it. The closest we come to electro-sensing is being able to feel our hairs stand up on end if there's a balloon charged with static electricity nearby.

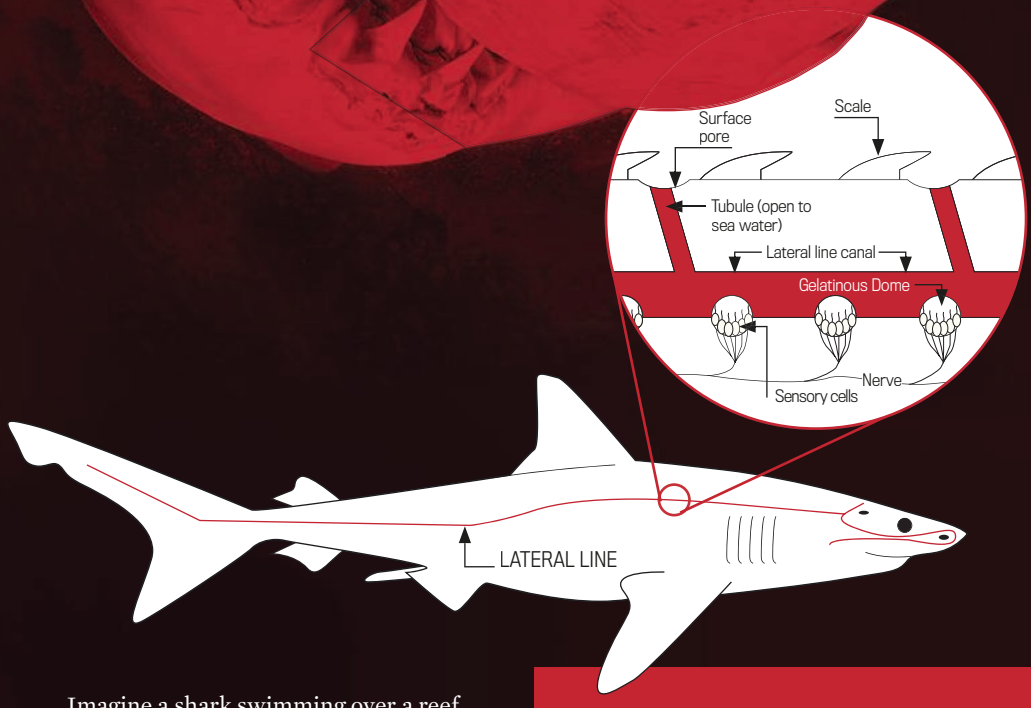
Make a movement in the water and the pressure sensors running along the length of this Great White will pick it up

SHARK *PRESSURE*

THE ULTIMATE MOTION DETECTOR

SHARKS ARE THE kings of the sensory world. They have incredible sight and hearing, sensitive nostrils and tastebuds, delicate touch detectors and the ability to electro-sense. But they have one other sense that completes this amazing set, giving them a completely different type of information. This is their lateral line system, and it allows them to detect tiny pressure changes in the water around them.

On each side of the shark's body, a jelly-filled canal runs from the head to the tail, just underneath the skin. The jelly is exposed directly to the water at intervals via pores, and as the pressure changes in the water, it pushes and pulls gently on the jelly, making it flow inside the canal. Hair cells protrude into the jelly, and as they move backwards and forwards with the flow, they send nerve signals back to the shark's brain. This system is incredibly sensitive, picking out the tiniest changes in pressure at single locations, and also pressure gradients along the length of the shark.



Imagine a shark swimming over a reef. As smaller fish swim past, they leave a wake of disturbed water behind them, and this wake can last up to 30 seconds. Larger fish leave larger and longer-lasting wakes. A crashing wave above might send a pressure pulse down into the water. The ocean surrounding the shark is full of delicate patterns, flowing swirling water movements, and each pattern tells a story. The lateral lines let the shark listen in to what the structure of the water itself has to say. This complements the rest of the shark's senses perfectly. Sensory knowledge is power, and the shark has it all.

HOW WE COMPARE

AIR DOESN'T TRANSMIT pressure pulses as well as water, so direct pressure sensors aren't much use. We might detect a breeze because it cools our skin, or because hairs on our arms are moved. If there's a large change in air pressure, we may detect it indirectly – when our ears 'pop', they've readjusted. Of course humans hear pressure differences as sounds, but we have nothing to match the lateral lines of sharks.

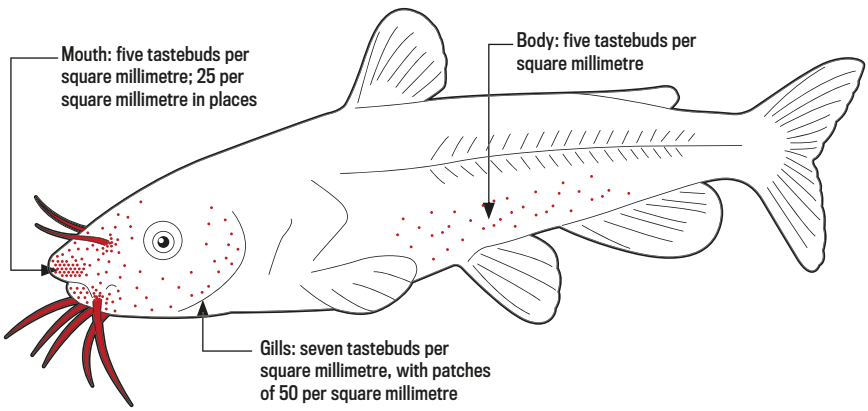
The catfish is able to enjoy the taste of its dinner long before it actually eats it

CATFISH *TASTE*
THE SWIMMING TONGUE

ON MOST ANIMALS, it's easy to point to the sense organs. They're located in specific places on the animal's body. But in some cases, evolution has thrown that limitation out of the window. For example, the channel catfish has been described as a 'swimming tongue', because its entire body is covered in taste receptors. There are higher concentrations on its lips and on the barbels that protrude from its face (their similarity to whiskers is why they're called catfish), but there are also four or five taste buds per square millimetre over the whole of the rest of its body. The detector molecules are at the surface of the skin, continually probing the water.

It sounds as though the catfish would be overwhelmed by the variety of chemicals from plants, animals, humans and anything else in the water. But these taste receptors are very specific, firing only when two types of amino acid float past. These types are common in invertebrates, and when it senses them, the catfish starts snapping.

The catfish can also detect and swim up a concentration gradient – closer to the invertebrate, the amino acids will be more concentrated. Near the bottom of a muddy stream where visibility is poor, a sense that can lead you right to dinner is a really valuable asset.



HOW WE COMPARE

OUR SENSE OF taste is pretty sophisticated, and we can detect many more flavours than a catfish. We get a huge amount of information about our food, because we have many types of flavour receptor. For example, a sweet flavour indicates an energy-rich food, and bitterness warns us of potentially toxic chemicals.

PHOTO: GETTY. YANN HUBERT/FLPA ILLUSTRATION: ACUTE GRAPHICS

DOLPHIN *HEARING*
A MASTER OF ACOUSTICS

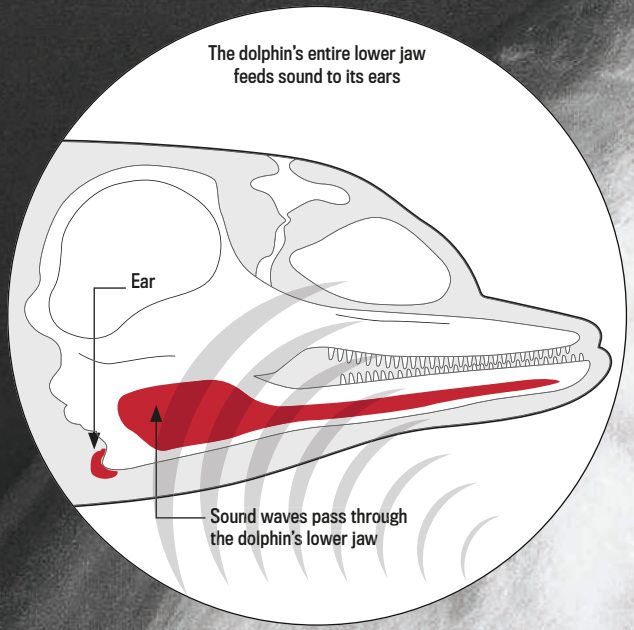
THE MAMMALIAN EAR is a sensory marvel. Our ears funnel sound down to the inner ear, the cochlea, into a fluid-filled tube lined with hairs. Different parts of the tube vibrate in response to different frequencies, and so as a sound travels down the tube, the fluid vibrates in specific places along its length. The tiny hairs are moved by the vibrating fluid, and they send nerve signals to the brain.

Evolution has shown just how much the ear is capable of. About 50 million years ago, there was a land mammal called a pakicetid. The descendants of this animal moved into the ocean, and split into two groups: baleen whales, like the blue and fin whales, and toothed whales, like orca, dolphins and sperm whales. The baleen whales evolved to use very deep sounds to communicate, and their cochlea is adapted to hear frequencies as low as 3Hz. The toothed whales went the other way, using high-frequency echolocation to hunt. It's thought that some dolphins can hear up to 280kHz. So this technique for hearing works over at least 17 octaves, a huge range, although no single animal can hear all of it.

But in spite of having very sensitive hearing, whales and dolphins don't have external ears. There's no need, because sound travels from water into the dolphin's body quite easily. Sound travelling through air will just bounce off your body, so land mammals need an external ear to help steer the sound inside. Instead of being funnelled down a small hole on the side of the dolphin's head, most of the sound passes directly into the lower jaw and along the bone to reach the ear. Their whole jaw is doing the listening. So for a dolphin, there's no equivalent of sticking your fingers in your ears! ■

HOW WE COMPARE

WHEN IT COMES to hearing, humans are pretty impressive. We can hear about 10 octaves, from around 20Hz to 20kHz. We can also detect a huge range of loudness without damaging our ears. The faintest sounds that we can hear move our eardrum a million times less than the loudest sounds we can hear. Of all our senses, hearing is probably the one we are best equipped for, and the one we notice the least.



DR HELEN CZERSKI is a physicist, oceanographer and BBC science presenter who appears regularly on *Dara O Briain's Science Club*

The scientific legacy of World War I

On the 100th anniversary of the war, **Ned Lebow** explores the more surprising advances that came out of the conflict

Blood transfusions

EARLY ATTEMPTS TO transfuse blood into humans often proved fatal because of an immune response that destroys red blood cells. In 1901, Karl Landsteiner of Austria discovered that humans had different blood groups and in 1907, the Czech Jan Janský identified four distinct groups.

The first transfusion of stored blood was performed in 1914 by Belgian physician Albert Hustin. British surgeon Geoffrey Keynes would later devise a portable machine to preserve blood which would facilitate battlefield transfusions, while it was an American physician, Oswald Hope Robertson, who created the first blood bank in France during the war.

These transfusions required blood collection and typing, storage and accurate matching of blood type from donor to patient. Doing this helped forge new links between civil servants and the medical profession that would prove essential for later developments such as the National Health Service.

Blood transfusions became common during the last two years of the war

Albert Einstein and Sir Arthur Eddington together in Cambridge, 1930

General Relativity

FOR THE MOST part the conflict stifled scientific progress, but in one case the thirst for knowledge overcame the war. Britain had banned the circulation of German scientific literature, which infuriated Arthur Eddington, the chief astronomer at the University of Cambridge. This was because he had noticed that the orbit of Mercury varied much less than Newton's laws suggested and suspected Einstein's theory of General Relativity held the answer. One of its key ideas is that space is shaped by mass, which provided an explanation of Mercury's anomalous orbit. Eddington realised that he could prove Einstein's contention that light waves are deflected by mass by taking pictures of stars during the solar eclipse of May 1919. He overcame the anti-German sentiment of the Royal Society to gain funding for an expedition to the West African island of Príncipe, where the eclipse would be total. Photographs that Eddington analysed provided the first observational confirmation of Einstein's theory.

Mass manufacturing

THE WAR MADE huge demands on production and distribution. Weapons and supplies had to be produced in vast quantities. By 1916 the second largest concentration of British nationals outside London was the British Expeditionary Force in France. Keeping these forces fed, clothed and supplied required new railways, warehouses, barracks, hospitals and roads. Just 1.5km of trench required 1,450km of barbed wire, six million sandbags, 28,320m^3 of timber, and 33,445m^2 of corrugated iron. Production and distribution need labour, and this was increasingly supplied by women.

As for science specifically, in 1914 Britain imported most of its scientific equipment from Germany. It now had to manufacture its own and draw on native scientific knowledge. All this helped to professionalise science and encourage science education, and led to the creation of numerous state and public scientific institutions.

World War I saw women entering the workforce in vast numbers

PHOTO: SCIENCE AND SOCIETY X4, SCIENCE PHOTO LIBRARY

In 1919, Alcock and Brown made the first non-stop transatlantic flight in a World War I Vimy bomber

Aviation

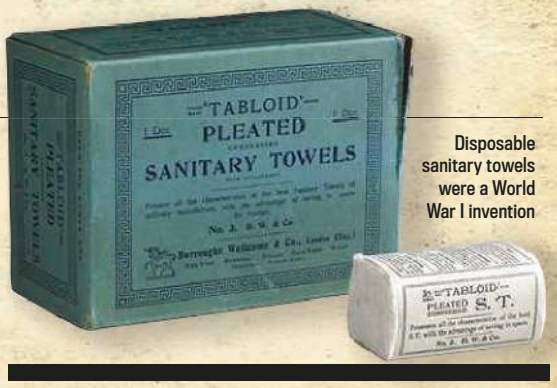
EARLY AEROPLANES were handicapped by the weight of their engines, which had steel radiators and water for cooling. In 1908, French engineers invented the rotary engine, which had spinning, air-cooled cylinders. Aircraft engines in 1914 produced a measly 50hp, but the output was soon greatly improved by British, French and German engine manufacturers competing for aerial supremacy.

For example, the Rolls-Royce Eagle and Falcon were the first in a famous line of engines. The Mark VII had 375hp, powering the Vimy heavy bomber that John Alcock and Arthur Whitten Brown flew across the Atlantic in June 1919. Better wings were also developed to exploit the power of these new engines. At the Institute for Theoretical Physics at the University of Göttingen, Ludwig Prandtl did pioneering work on aerofoils, drag and the lift properties of wings. Using a wind tunnel, Prandtl pioneered the science of aerodynamics and created the 'thick wing' that gave fighter planes the ability to climb at much steeper angles without stalling.

Better aircraft needed better control systems and navigation. Early ground-to-air signalling used flags and lamps. But in 1916, technicians in San Diego sent a radio message 225km (140 miles), and then messages between planes. By 1917, the US Army had two-way radios on its fighter planes in France.

Sanitary towels

PUBLIC HEALTH HAD improved greatly during the 19th Century, and World War I witnessed further improvements with the development of the sanitary towel. Where women had traditionally used washable underwear or rags, French nurses on the frontline were the first to employ the newly invented cellulose material that was used for wartime bandages. British and American nurses soon adopted the same practice, as did many women in uniform. In 1920, US company Kimberly-Clark began to produce 'cellucotton' sanitary towels commercially under the brand name Kotex (cotton plus texture).



Disposable sanitary towels were a World War I invention

RICHARD NED LEBOW is a professor in the Department of War Studies at King's College London, and author of *Archduke Ferdinand Lives: A World Without World War I*

The Rosetta mission will deploy a lander to analyse the make-up of comet 67P/Churyumov-Gerasimenko – it should touch down in November

THE COMET CHASER

This month, 10 years after it launched, the Rosetta spacecraft will catch up to a comet travelling at 135,000km/h, before deploying a lander that will reveal its secrets. **Will Gater** takes a look at the mission

PHOTO: ESA/ANDY POTTS

SOME 69KM (43 MILES) above the Atlantic Ocean, things were going very wrong for the Ariane 5 rocket. Minutes previously, it had thundered smoothly off the pad in French Guiana carrying a cargo of satellites. Now, though, its engine nozzle had failed and it was straying from its planned trajectory dramatically. Less than eight minutes after lift-off, the rocket self-destructed, showering the sea below with debris.

The malfunction would prove costly in a multitude of ways, but for the team working on the European Space Agency's Rosetta mission, it marked the beginning of an especially worrying period. The same type of rocket was due to propel their spacecraft skyward, towards an historic rendezvous with the comet 46P/Wirtanen, in January 2003 – less than four weeks later.

As launch day approached, it became clear that the fallout from the earlier Ariane 5 failure would see Rosetta lose its one shot at reaching the icy visitor. "Rosetta was effectively put in a shed, and no-one knew what was going to be done," says Rosetta project scientist Matt Taylor, who joined the team in 2013.

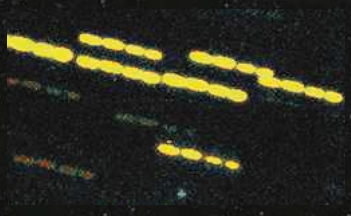
SECOND TIME LUCKY

The spacecraft didn't languish there for long, though. Rosetta's scientists soon identified another suitable target for their mission, and in March 2004 the probe safely blasted off for the comet 67P/Churyumov-Gerasimenko. This month, it will at last arrive at the comet, giving Taylor and his colleagues a long-awaited close look at Rosetta's objective.

Rosetta launched onboard an Ariane 5 rocket in 2004

TIMELINE

JANUARY 2003
A MISSED OPPORTUNITY



Rosetta was supposed to launch in January 2003 and visit the comet 46P/Wirtanen. But concerns about the rocket meant that the mission missed this launch opportunity.

MARCH 2004
LIFT-OFF!

Rosetta eventually blasted off from Kourou, French Guiana, on 2 March 2004. Now it was heading for an entirely different comet, Churyumov-Gerasimenko, which had been discovered in 1969.

JANUARY 2014
THE SPACECRAFT AWAKENS

After several years of travelling through space in a state of electronic hibernation, the Rosetta spacecraft was woken up on 20 January 2014. Soon it would be taking its first long-distance images of Churyumov-Gerasimenko.

MID-2014
BURN, BABY, BURN

For the past few months Rosetta has been making a number of thruster 'burns' that are necessary to ensure it makes a successful rendezvous with Churyumov-Gerasimenko. Some burns have lasted up to seven hours.

PHOTO: ESA X6, ESO

Churyumov-Gerasimenko was first observed by Romanian astronomer Klim Ivanovych Churyumov in 1969

The Rosetta spacecraft's array of solar panels being assembled and tested in an ESA clean room

The team already know a fair bit about Churyumov-Gerasimenko, of course, thanks to ground- and space-based observations. It's what's known as a 'periodic' comet – it orbits our star in almost 6.5 years – and it rotates once every 12.4 hours. "It's a bit of a potato shape," says Taylor, "between four and five kilometres across, depending on which way you measure it."

Crucially, the team also believe it not to be a cometary wild child. "Comets are inherently unpredictable," explains Taylor. "But by choosing a periodic comet we have some level of predictability as to its activity. We had measurements from its entire previous orbit around the Sun, which gave us an idea of how it was going to behave."

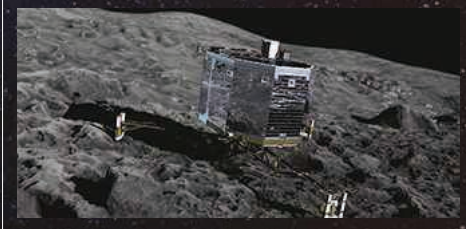
"Like all comets, Churyumov-Gerasimenko should become more active as it nears the Sun"

Churyumov-Gerasimenko is unlikely to disintegrate in the spectacular fashion that comet ISON did earlier this year, then, but like all comets, it should become more and more active as it nears the Sun. Rosetta will be in a perfect position to study these developments,

AUGUST 2014
ARRIVAL AT 67P

In August 2014, Rosetta will finally arrive at Churyumov-Gerasimenko. The spacecraft will enter orbit around the comet and mimic its trajectory as it moves further into the inner Solar System.

NOVEMBER 2014
PHILAE TAKES FLIGHT



November 2014 will see the historic event that Rosetta scientists have been waiting years for: the Philae lander will attempt to make a soft landing on the comet's nucleus.

AUGUST 2015
67P AT PERIHELION

On 13 August 2015, Churyumov-Gerasimenko will reach perihelion – that is, the point in its orbit when it is closest to the Sun. Scientists will be watching intently to see how the comet behaves here.

DECEMBER 2015
MISSION ENDS?

Rosetta's mission is funded to last until December 2015. However, the team is already exploring ways in which the mission could be extended beyond this point, when the craft's fuel and power supplies will be dwindling.

because it will be doing something that no mission has ever done before: flying right alongside the comet.

"Previous missions have flown by other comets at kilometres-per-second speeds, and at hundreds of kilometres distance. So you only get a snapshot, you don't see much of an evolution," says Taylor. "With Rosetta we're going to get in within one metre per second relative speed with the comet for over a year."

"We'll be able to see regions of activity start, be fully active and then reduce again"

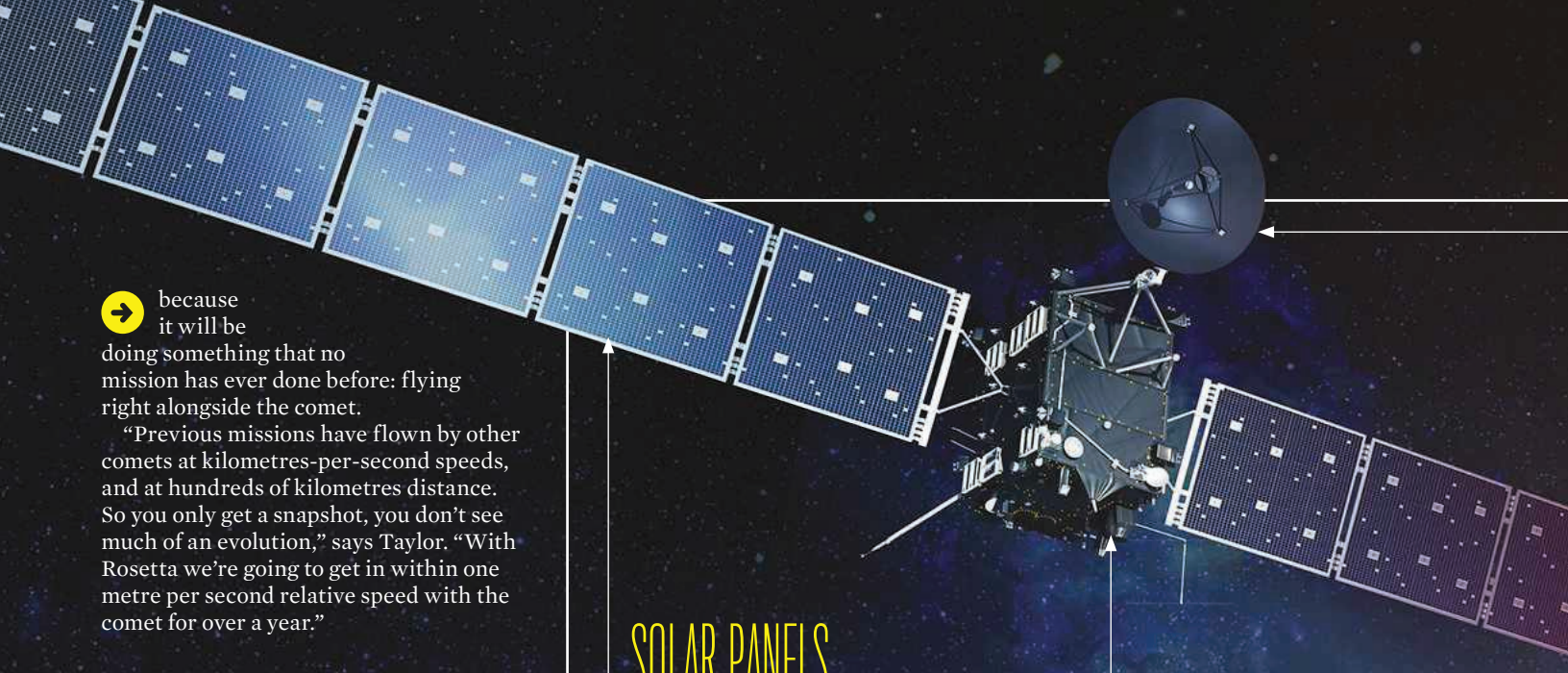
Matt Taylor, Rosetta project scientist

That will allow the scientists to watch as the warmth of the Sun causes the comet to vent thousands of kilograms of dust and gas he says. "We'll be able to see regions of activity start, be fully active and then reduce again. Just to have that observation gives you that leap forward in really understanding how comets work."

GOING BOLDLY...

Rosetta's most nail-biting moment, though, will come this November, when the spacecraft will send a small lander, called Philae, to the frozen surface of Churyumov-Gerasimenko. Its instruments and cameras should provide scientists with an unprecedented view of a cometary nucleus – the ice and rock 'body' of the comet. "As it touches the surface, a little thruster will push it down on the top," says Taylor. "As that occurs, ice screws from each of the three feet will punch down into the surface and then two harpoons will fire down."

Once it's securely on the comet, Philae will start to collect and analyse samples as well as send back high-resolution pictures of its surroundings. It'll also work with Rosetta to examine the three-dimensional interior structure of Churyumov-Gerasimenko using radio waves.



SOLAR PANELS

14m-long solar panels deliver power to the spacecraft's systems and instruments

SPECTROMETERS

Several of Rosetta's instruments feature sensitive spectrometers for studying the comet's chemical make-up

ROSETTA'S TOOLKIT

If you're going to spend 10 years and a billion Euros to get to a comet, you'd best make sure you're carrying the right equipment to study it properly when you get there...

PHOTO: ESA/ANDY POTTS

COMMUNICATIONS

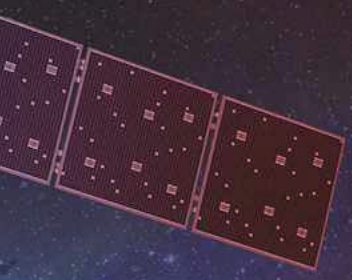
Rosetta sends and receives data to and from Earth via a 2.2m-wide dish antenna

PHILAE LANDER

The three-legged Philae lander will be deployed in November. It's equipped with an array of sensors and experiments that will reveal the comet's make-up in unprecedented detail

CAMERAS

Both Rosetta and the Philae lander are equipped with high-resolution cameras to image Churyumov-Gerasimenko



DRILL

A drill extracts samples from the comet before they're analysed on board

SESAME

Mounted on each of Philae's feet, the Surface Electric Sounding and Acoustic Monitoring Experiment records the comet's physical and electrical properties

Inside Rosetta Mission Control at the European Space Operations Centre in Darmstadt, Germany

CALL OF THE COMETS

Humanity has been fascinated by these night-sky wanderers since ancient times

IN SENDING A probe to Churyumov-Gerasimenko, Rosetta scientists are simply following in the footsteps of countless others who've sought to decode the story of these enigmatic, icy wanderers. This fascination with comets has existed for much of human history, says project scientist Matt Taylor. "It dates back thousands of years, when there is documented evidence of people monitoring these bodies," he says. "They were originally seen as something that was a sign of foreboding, of something bad happening."

In recent years, we've come to realise that comets are a window into the past, and may even hold the key to understanding how life arose on Earth. "From a modern science perspective we look at them as being a frozen time capsule of what the conditions were like during the formation of the Solar System, some 4.5 billion years ago," says Taylor. "The planets formed, and from the leftovers of that process we had the comets, hurled out into deep freeze beyond the outskirts of the Solar System, as well as the asteroid belt."

Taylor likens the task of unravelling a comet's history to that of forensic experts at a crime scene. "You pick up dust in a forensic scene to get clues as to what was going on and who was there," he says. "In the same way we'll gather dust, chemicals and isotopes from the comet's coma to work out where it came from, how it got to where it is today and also what was going on at that time."

"Imagine you've got the orbiter on one side of the comet and the lander on the far side, with a radio signal propagating through it," says Taylor. "As Rosetta orbits the comet you'll see the variations [in the signal] and be able to build up a reasonably accurate picture of what the nucleus looks like."

"In recent years, we've come to realise that comets are a window into the past"

Taylor is confident the lander will make it down to Churyumov-Gerasimenko. "It is very risky," he admits. "But then if it was easy, we'd have done it already." ■

WILL GATER is an astronomy journalist and author. Find him on Twitter: @willgater

PHOTO: ESA/ANDY POTTS

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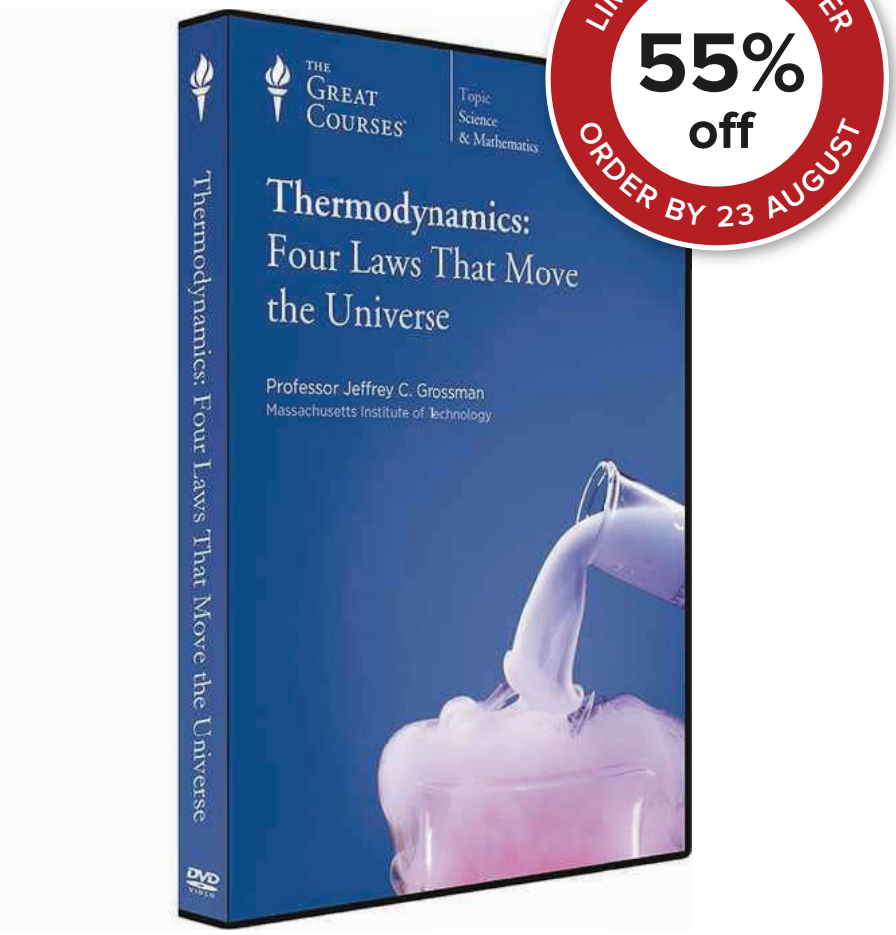

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8. Entropy—The Arrow of Time
9. The Chemical Potential
10. Enthalpy, Free Energy, and Equilibrium
11. Mixing and Osmotic Pressure
12. How Materials Hold Heat
13. How Materials Respond to Heat
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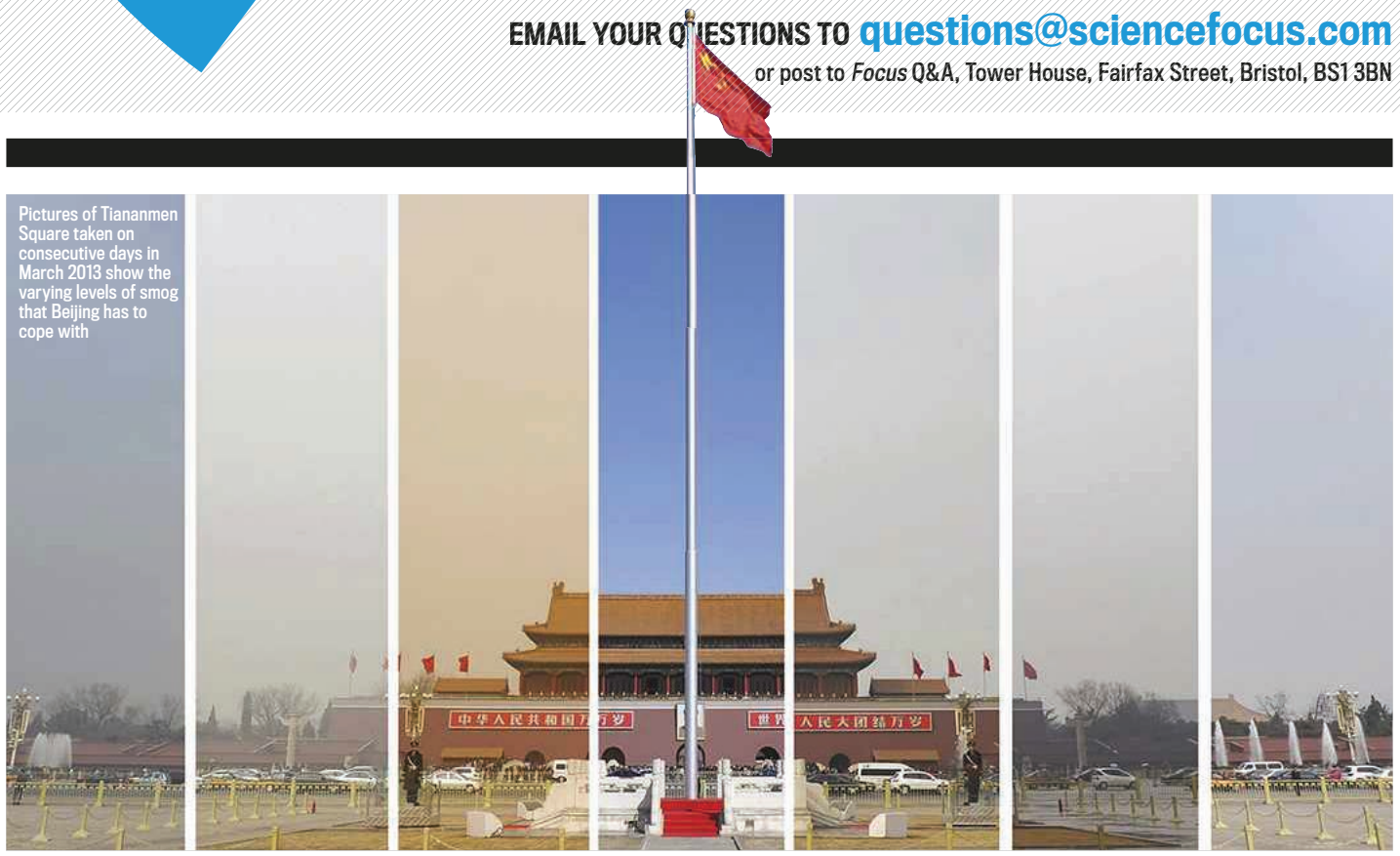


Pictures of Tiananmen Square taken on consecutive days in March 2013 show the varying levels of smog that Beijing has to cope with

Q **SAMUEL LENNOX,** READING

What is smog and how can it be prevented?

A A COMBINATION OF the words 'smoke' and 'fog', the term emerged around a century ago to describe the dense, choking mix of gases and soot that was becoming common in big cities. Back then, smog was generated by coal-burning homes and factories spewing out a potentially lethal cocktail of ozone and oxides of carbon, sulphur and nitrogen. The Great Smog of London in 1952 killed over 4,000 people.

Today, houses and factories have been replaced by traffic as the principal cause of smog. Last March, driving restrictions were imposed in Paris, which suffers worse than other European capitals because of the popularity of cars running on cheap but dirty diesel. The problem is especially severe in sunny weather, when the sunlight interacts with pollution to produce a noxious 'photochemical' smog.

Yet the world leader in smog production is China. The pollution from its quarter of a billion cars has been implicated in around three million pollution-linked deaths each year, with China's own scientists describing Beijing as "close to uninhabitable". In May, the Chinese government announced it was going to attempt to control smog by curbing car use in Beijing, and by scrapping over five million old, heavily-polluting cars. **RM**

PHOTO: CORBIS

In Numbers

49.8 MILLION

kilograms is the weight of cigarette filters discarded every year in the US. The filters contain toxic chemicals that find their way into the environment.

Q **HASAN CUTHBERT,** CAMBRIDGE

Could there be non-carbon-based life?

A IT'S PROBABLY NO accident that all known life uses chemistry based on carbon atoms. Carbon is the fourth most abundant element in the Universe, after hydrogen, helium and oxygen, and it reacts to form complex and fairly stable molecules with lots of other different elements. Silicon is in the same group of the periodic table as carbon, but it's a large atom and doesn't easily form the double bonds that are important in organic chemistry. The silicon equivalent of hydrocarbon chains are called silanes but they are much less stable – silane itself (SiH_4) explodes on contact with air.

But that doesn't mean non-carbon life is impossible. In 2009 researchers at Glasgow University demonstrated that molecules based on tungsten oxide can form membranes that show many similarities with living cell membranes. Life of this sort is unlikely to be common in the Universe, but there may be some metal-rich planets where it thrives. **LV**

A tungsten oxide 'cell' created at the University of Glasgow

Q **DANIEL BURGESS,** SHEFFIELD

Is handedness found in other animals?

A NINETY PER CENT of humans are right-handed, and we're better with our favoured hand for all tasks. In animals the bias is much weaker and can vary from task to task. This is probably just a result of better muscle co-ordination for the hand or paw that they happen to use more often – a self-reinforcing effect. Some studies have shown as much as 70 per cent right-handedness in chimpanzees but others have found much lower percentages. Sulphur-crested cockatoos are a notable exception – virtually all of them are left-footed. **LV**

Sulphur-crested cockatoos are one of the few animals to exhibit handedness... or is that footedness?

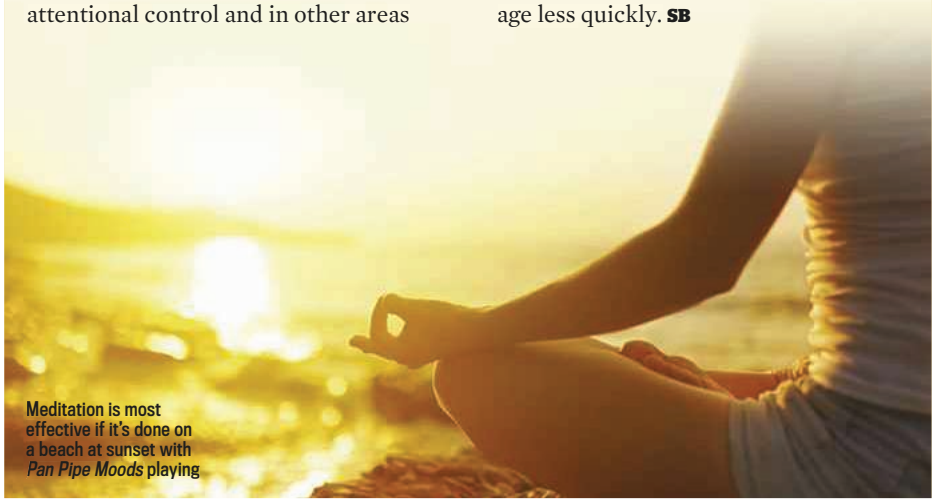
Q **SARAH HAYNES,** LONDON

Can meditation physically change your brain?

A YES, AND THOSE changes can be either short-term – occurring during the meditation itself – or long-term, occurring over years of practice.

All forms of meditation involve training the attention. 'Open' meditation means paying equal attention to everything without judging or being distracted. 'Closed' or 'concentrative' meditation entails paying intense and steady attention to just one thing, such as your breath, or a sound or feeling. In line with this, brain scans show increased activity in parts of the frontal cortex associated with attentional control and in other areas depending on the kind of meditation. Emotional responses are also affected and increased activity is found in the circuits underlying positive emotions and emotional control.

Studying long-term effects is harder because any findings might be due to years of meditation, or might be just because people who learn to meditate and persevere with it for a long time are different from people who do not. Even so, research suggests that long-term meditators show more coherent activity across different brain areas, and that their brains age less quickly. **SB**



Meditation is most effective if it's done on a beach at sunset with *Pan Pipe Moods* playing

PHOTO: THINKSTOCK X4, LEE CRONIN, SCIENCE PHOTO LIBRARY

QUESTION OF THE MONTH

WINNER! Charlie wins a copy of *How Many Socks Make A Pair?* by Rob Eastaway (Aurum Press)

Even the empty space in this vacuum chamber has a temperature

Q CHARLIE MACK, UCKFIELD

What temperature is a vacuum?

A THE TEMPERATURE of a substance is a measure of the kinetic energy of its constituents. So, for example, nitrogen at room temperature consists of molecules whizzing around with typical speeds of over 1,800km/h. Yet in principle at least, a vacuum is utterly devoid of constituents, making this definition of temperature problematic.

In practice, however, genuinely perfect vacuums don't exist. Quantum theory implies that even apparently 'empty' space is seething with energy, as a consequence of the uncertainty principle. The 'hardest' vacuum we know of in real-life – that is, the closest to a perfect vacuum – is space, yet even this contains an average of around one particle per cubic metre, plus radiation left behind from the Big Bang. After 14 billion years, this radiation now has an energy corresponding to a temperature of around 3°C above absolute zero (–273°C), making this the temperature of the hardest known vacuum. **RM**

Q BERNADETA DADONAITE, LONDON

Why don't all dark clouds bring rain?

A common sight in the British Isles...

A THE DARKNESS OF rain clouds is the result of the sheer number of droplets in them hampering the passage of sunlight. But numbers alone aren't enough to cause rain: the individual droplets must also be big enough to overcome the warm air currents rising from the ground. And if they aren't, they stay put. **RM**

Q EMILY THOMPSON, STOCKPORT

If you are allergic to penicillin, can you eat Stilton?

A THE ANTIBIOTIC PENICILLIN is made from the fungus *Penicillium chrysogenum*. Stilton and most other blue cheeses do use *Penicillium* mould to create the blue veins, but they use a different strain (*P. roqueforti*) and the whole mould, rather than the penicillin extract. It is possible to be allergic to the drug and still be able to eat the cheese with impunity, although there are also people who are allergic to both. It's also worth noting that only 20 per cent of people who think they are allergic to penicillin, actually are. **LV**

Stilton is made from a different strain of the *Penicillium* mould that is used to make the drug penicillin

TOP TEN

TOP TEN LARGEST BUTTERFLIES

1. Queen Alexandra's Birdwing
Wingspan: up to 31cm
Distribution: Papua New Guinea, Indonesia

2. Goliath Birdwing
Wingspan: up to 28cm
Distribution: New Guinea, Indonesia

3. Giant African Swallowtail
Wingspan: up to 23cm
Distribution: West and Central Africa

= 4. Rippon's Birdwing
Wingspan: up to 20cm
Distribution: Moluccas and Sulawesi, Indonesia

= 4. Wallace's Golden Birdwing
Wingspan: up to 20cm
Distribution: Maluku Islands, Indonesia

= 6. Palawan Birdwing
Wingspan: up to 19cm
Distribution: Palawan, Philippines

= 6. Buru Opalescent Birdwing
Wingspan: up to 19cm
Distribution: Buru, Indonesia

= 8. Chimaera Birdwing
Wingspan: up to 18cm
Distribution: New Guinea and Java, Indonesia

= 8. Magellan Birdwing
Wingspan: up to 18cm
Distribution: Philippines and Orchid Island, Taiwan

10. Miranda Birdwing
Wingspan: up to 17cm
Distribution: Sumatra and Borneo

PHOTO: ALAMY X3, WIKIPEDIA X6, NATURHISTORISCHES MUSEUM WIEN, SCIENCE PHOTO LIBRARY

Q PHIL CROSBY, BY EMAIL

How loud was the Big Bang?

A ALTHOUGH THERE WERE no humans around to hear it, the Big Bang did create sound. We can deduce the scale of these sound waves by observing the tiny temperature variations in the relic radiation from the Big Bang, called the Cosmic Microwave Background. Their wavelength is measured in hundreds of thousands of light-years, so the 'notes' are actually far too low to be heard by humans.

The details are rather complicated but as a rough estimate we can calculate the loudness of these waves to be between 100dB and 120dB. Although this is near the human ear's pain threshold (similar to standing next to a chainsaw or about 100m from a jet engine), it is by no means the loudest thing you could experience. It is thought that the eruption of Krakatoa produced sound waves at about 180dB, while blue whales 'talk' at up to 188dB. **AG**

You'd expect something called the 'Big Bang' to make a noise, wouldn't you?

Q RICHARD O'NEILL, GLASGOW

Could man survive without insects?

A IT WOULD BE very difficult. Insects pollinate at least a third of the total volume of crops cultivated worldwide and many are useful predators of non-insect pests such as mites. Even if we managed to convert agriculture to purely wind-pollinated crops we would have to deal with an even more fundamental problem: the complete collapse of most ecosystems. The total biomass of insects vastly outstrips the mass of all vertebrates so insects are a vital part of most food webs. Without insects for them to eat, we would lose most reptiles and amphibians and about half of all the bird species.

Insects are also a very important part of the decomposition process that returns nutrients from dead plants and animals to the soil. The environmental catastrophe that resulted would probably totally disrupt agriculture for decades or more and leave us almost entirely dependent on the sea for food. **LV**

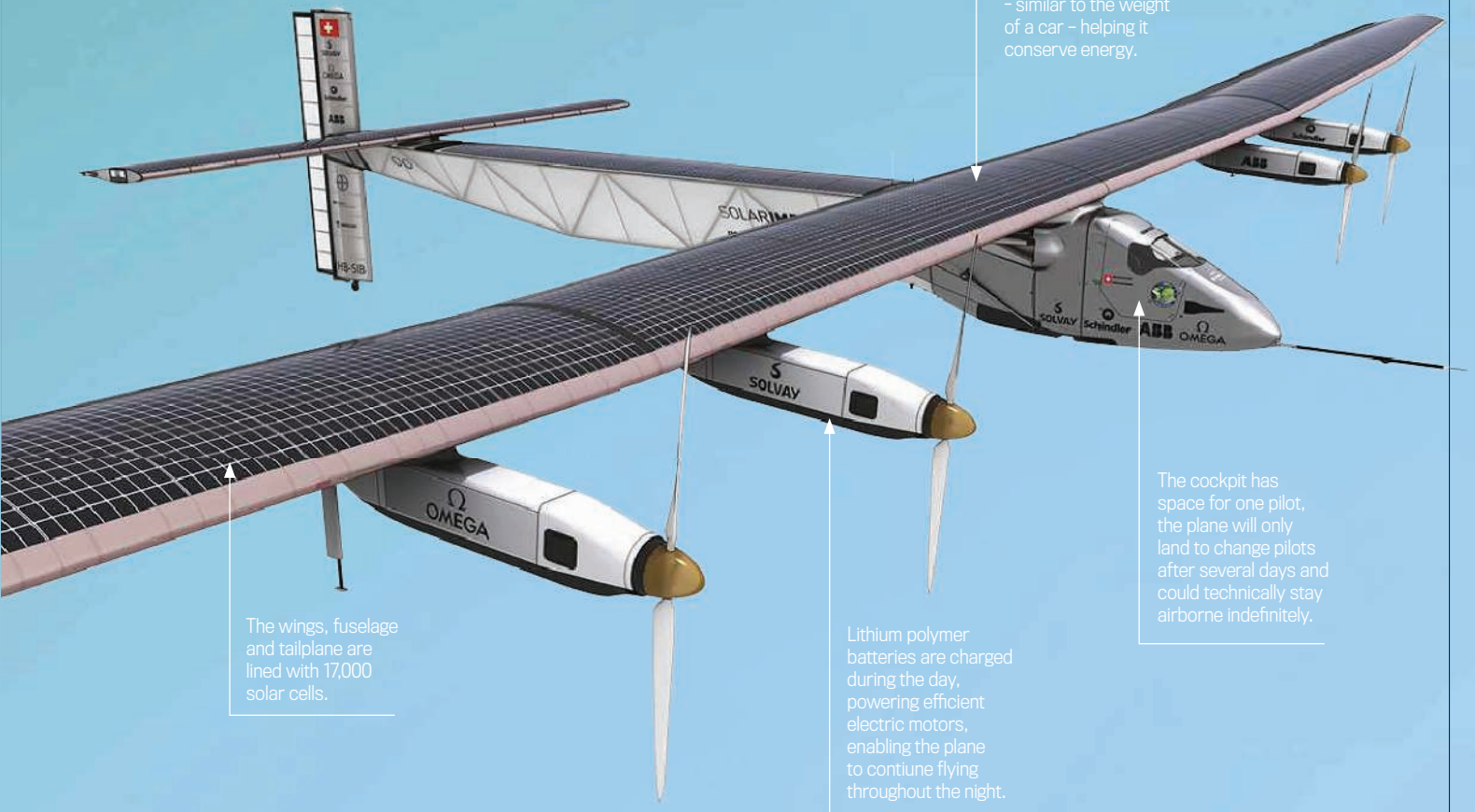
Next time you swat a fly, spare a moment to think that we depend on its kind for our very survival

HOW IT WORKS

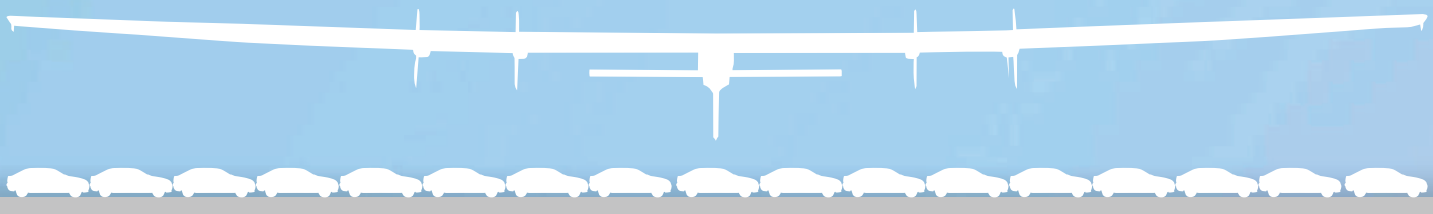
SOLAR IMPULSE 2

WITH A WINGSPAN of 72m it's wider than a jumbo jet, and yet it only weighs 2.3 tonnes. This is the Solar Impulse 2, a plane that's able to fly around the world non-stop without carrying an ounce of fuel. The wings are lined with over 17,000 solar cells that charge highly efficient lithium batteries. These are housed along the wing and deliver power to four electric motors and propellars.

With a top speed of only 141km/h (88mph), this plane isn't going to break any speed records, but the team behind it plan to fly around the world in 2015 in order to showcase the solar technology.



WINGSPAN



72m – roughly the length of 17 Ford Focus hatchbacks

Q **MARK ADAM,** WEYMOUTH

Can external sounds influence your dreams?

Kids: the ultimate in morning alarms

A YES. MANY PEOPLE have dreamed of a church bell ringing or a fire engine's siren, only to wake to the sound of their alarm. Sometimes dreams seem to build up gradually towards the final sound – walking miles to the church for example, or running through a blazing city before the fire engine arrives. This may seem impossible, or even paranormal, but it probably occurs as the brain tries to build a story from a lot of jumbled dream fragments as it wakes up. Dripping taps, distant voices, and traffic are often claimed to affect dream content.

In recent experiments thousands of people have used an app that plays different 'soundscapes' when they are dreaming. Those who listened to nature sounds were more likely to report dreaming of greenery and flowers while those who selected beach sounds were more likely to dream of sunshine holidays. **SB**

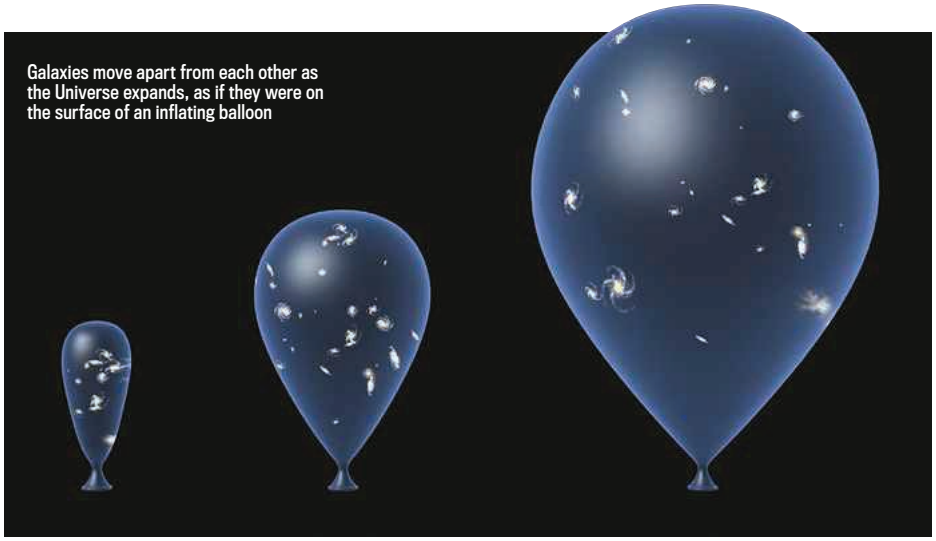
In Numbers

2,092km/h

is the speed the mite *Paratarsotomus macropalpis* would run if it were the size of a human. The sesame-seed-sized mite recently set a new record as the fastest land animal.

Q **JOHN BLANNING,** BRISTOL

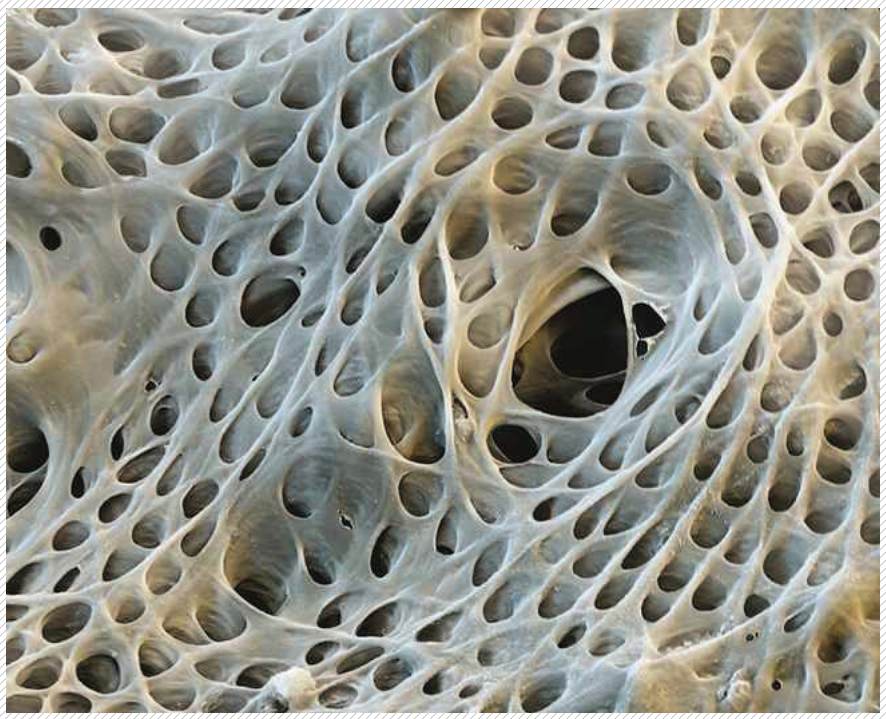
How can the Universe be infinite if it is expanding?



Galaxies move apart from each other as the Universe expands, as if they were on the surface of an inflating balloon

A THE EXPANSION OF the visible Universe is the result of the stretching of space between whole clusters of galaxies – a little like coins stuck to an expanding balloon. This stretching effect would still make sense whether the entire Universe were double, 10 times or even infinitely bigger than what we can observe. **RM**

WHAT IS THIS?



KNOW THE ANSWER?
Go to **sciencefocus.com/qanda/what** and submit your answer now!

LAST MONTH'S ANSWER:
Jonathan Newsam correctly guessed bacteria found in the belly button along with some fungal spores

PHOTO: GETTY, SCIENCE PHOTO LIBRARY X2, ALAMY, FEI COMPANY/FRANCISCO RANGEL

Q CHARLOTTE TUTTLE, CHICHESTER

Is there an advantage to having a beard?

A YES, IF YOU want to attract women, but only when beards are relatively rare. In Britain big beards are currently popular, but some say we have reached 'peak beard' and hairy chins will soon decline.

New research suggests that wearing a beard may be similar to what is known in biology as 'negative frequency-dependent sexual selection'. This means that a rare trait is more attractive to the opposite sex than a common one. In biology this effect depends on genes but in the case of beards it depends on an idea: deciding to shave or not. In the experiments nearly 1,500 women and 200 men were shown photos of men with varying amounts of facial hair. When most of the photos were of clean-shaven men the women preferred the bearded ones, and vice versa. **SB**

Bring back the razor! We're reaching 'peak beard' in Britain

Q PAULO ALMEIDA, BY EMAIL

Does a thunderstorm affect the hatching of eggs?

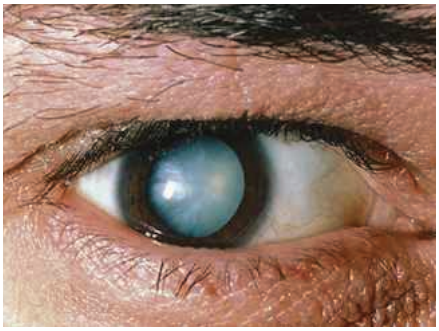
A lightning storm will have no effect on your ability to count your chickens

A ALTHOUGH THIS IS an oft-repeated bit of farmyard lore, it's almost certainly not true. I can't find any academic studies that have specifically looked for a connection (which is itself quite telling since it would definitely be in the poultry industry's interest to research this if it was remotely plausible). A 1972 study found no effect on hatching from sonic booms of low-flying aircraft, so we can rule out the sound of the thunder itself. And there's nothing particularly lethal about the humidity, temperature or ion balance of the air during a thunderstorm that might kill unhatched chicks. **LV**

Q PHIL CROSBY, BY EMAIL

Do cataracts affect iris recognition systems?

A IN THEORY, NO. Iris recognition systems use an algorithm to match the unique pattern of your iris; a cataract is a clouding of the lens, a different part of the eye. A 2004 study showed that cataract surgery can confuse the technology, but a later paper in *Nature* suggested surgery has no effect. It went on to report that iris recognition systems could be foiled by dilating the iris using eye drops. **GM**



Cataracts won't mean you can break into the Royal Mint

Q JAKE BOGDAN, SWITZERLAND

Why do children dislike vegetables?

A OUR EVOLUTIONARY ANCESTORS lived with lots of toxic plants and we evolved a gene that makes the toxins in these plants taste bitter to discourage us from eating them. Children probably evolved a stronger aversion to bitter tastes because they haven't yet learned which plants are dangerous. We learn which plants are safe and lose half of our taste receptors by the time we are 20, making vegetables taste less bitter. **LV**

Kids are merely trying to avoid a painful toxic death when they refuse to eat broccoli

Q **MALCOLM FRASER,** LEEDS

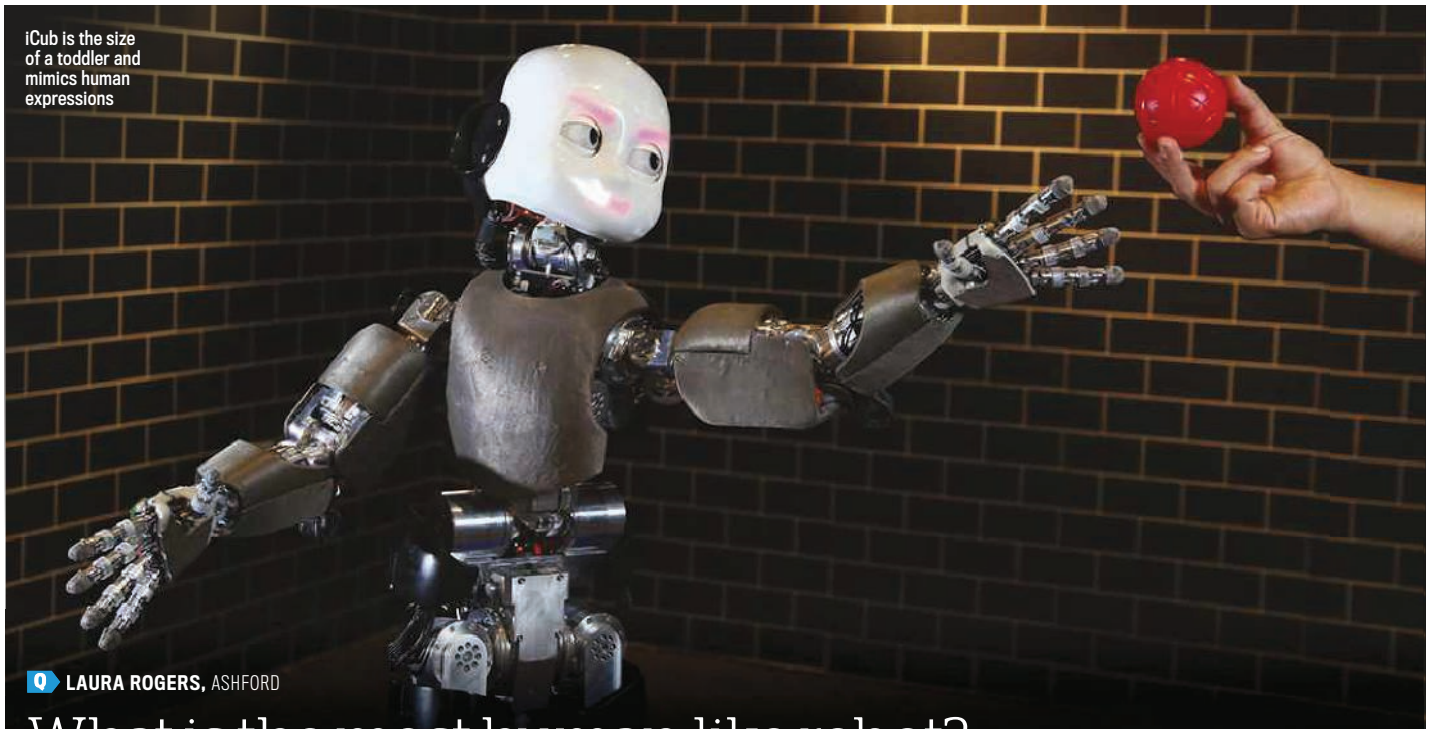
What's the most widespread material that can't be recycled?

A MOST OF US use a simple rule of thumb and throw anything made of metal, glass, plastic, paper or cardboard into the recycling bin. But there are lots of exceptions to this rule, many of them quite surprising. Old Yellow Pages directories seem like they were designed to be recycled, but by the time the book is a year old the yellow dye can't be removed and will contaminate an entire batch, so paper mills won't accept them. Wrapping paper is also too heavily dyed and often contains foil or plastic that is hard to separate. Juice cartons have a wax lining that can't be removed either. Light bulbs contain too many different materials to effectively recycle and aerosol cans have some leftover propellant that makes them dangerous to simply melt down.

Even with plastic containers, the only ones that are economical to recycle at the moment are milk and drinks bottles. The plastic in virtually all other packaging is either too expensive to sort and process, or not valuable enough. Some councils will accept them in your recycling box but they are simply sorted out by hand and thrown into landfill anyway.

But probably the most widespread unrecyclable is the crisp packet. The foil layer that keeps them fresh can't be separated and the vegetable oil contaminates the plastic anyway. We get through 13 billion packets every year in the UK. If we stitched them all into a giant blanket, it would completely cover the city of Birmingham. **LV**

The council had to lay on extra staff to clean up after the *Focus* office party



iCub is the size of a toddler and mimics human expressions

Q **LAURA ROGERS,** ASHFORD

What is the most human-like robot?

A DEVELOPED BY A Massachusetts robotics firm, PETMAN is a humanoid 'bot that walks, bends and waves its arms. It has been designed to help the US military try out chemical protection suits by mimicking the body movements of actual soldiers. PETMAN's gyrations are uncannily realistic, but he is not exactly interactive. He is not designed to talk or respond to users.

The iCub scores more highly in that department. I have shaken hands with one of 30 iCubs produced through a collaboration of European research institutions. The robot is about the same size as a human toddler and, unlike PETMAN, has a human-like face. The face is quite basic but it possesses eyes and some versions even have eyelids. Possibly because it is so infant-like, iCub is one of the most convincing human mimics I have come across. Its main goal is to aid research into the cognitive development of children. **GM**

Q SHAUN WALDREN, BY EMAIL

Could a dead Sun be reignited?

The Sun will begin to reach the end of its life in 5.4 billion years, becoming a red giant

A STARS USE THEIR nuclear fuel steadily through their lifetimes, initially converting hydrogen into other elements, and then 'burning' progressively heavier elements until their nuclear fuel is depleted. The rate at which they burn elements, which elements they burn and what eventually happens to them when their fuel is exhausted depends on their mass. It would be feasible to add mass to a star which is nearing the end of its life, postponing its death. Similarly, adding mass to a dead star (one that hasn't blown itself apart in the process of dying) could reignite it if its central density reaches the required threshold for nuclear fusion, but only if the right fuel is present.

There are mechanisms that could produce such events, but none are so far proven. Of course, stars that explode may eventually coalesce again and reignite as entirely new stars. **AG**

Q COLIN BONNICI, MALTA

Why do we feel drowsy after eating a large meal?

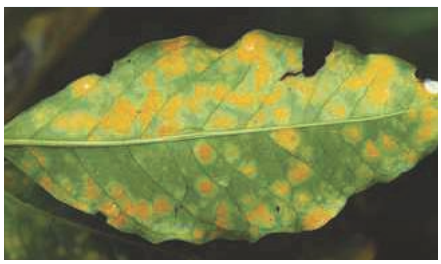
A CONTRARY TO MYTH, it's not caused by blood being diverted from your brain to your stomach. The drowsiness is partly because your body activates a 'rest and digest' mechanism (the opposite of the 'fight or flight' response) and partly because high carbohydrate meals increase the levels of melatonin in the brain, which makes us feel sleepy. **LV**

Steak and chips will induce a 'rest and digest' response

Q ANDREW GLOSSOP, CHALFONT ST GILES

Do plants have immune systems?

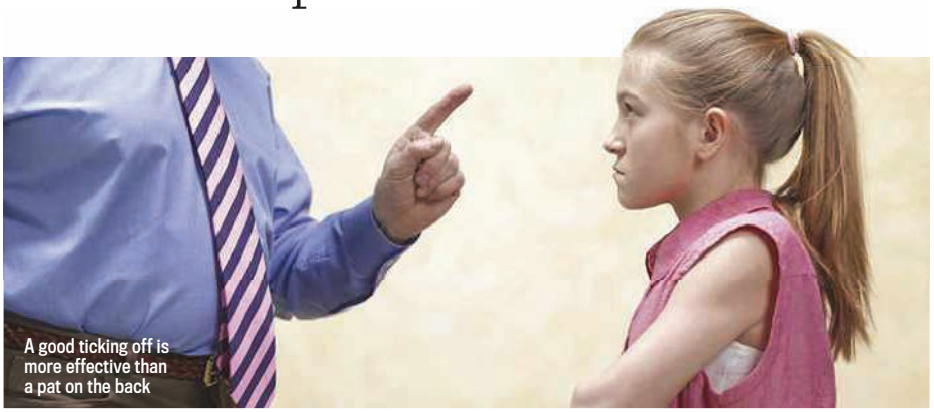
A YES, BUT THEY aren't like ours. Plants don't have a circulatory system so they can't easily transport white blood cells around their bodies. Instead, each plant cell has its own armoury of techniques to attack an infection. Cells can thicken their walls, release antimicrobial compounds and block the RNA genetic code of some viruses. If that doesn't work, they will commit suicide to deny the invader access to their resources. Plant cells also release messenger chemicals to forewarn other nearby cells and can even recruit helpful bacteria to fight for them by releasing attractive chemicals from their roots. **LV**



Plants are able to wage war on infections to stay healthy

Q HELEN DAWES, LEICESTER

Why do we remember criticism more than praise?



A good ticking off is more effective than a pat on the back

A THIS IS AN aspect of what psychologists call 'negativity bias'; a tendency that is found in other species and may have evolved to keep us from harm. We are more likely to remember scary or painful events than happy ones, remember unkind actions rather than kind ones, and process bad news more thoroughly than good. In relationships, many examples of praise are needed to counteract one unpleasant criticism.

As for self-perception, we are highly motivated to avoid bad self-definitions and so react with stronger emotions to criticism than to praise. On the other hand, most people over-estimate their own positive qualities and this can overcome the negativity bias. **SB**

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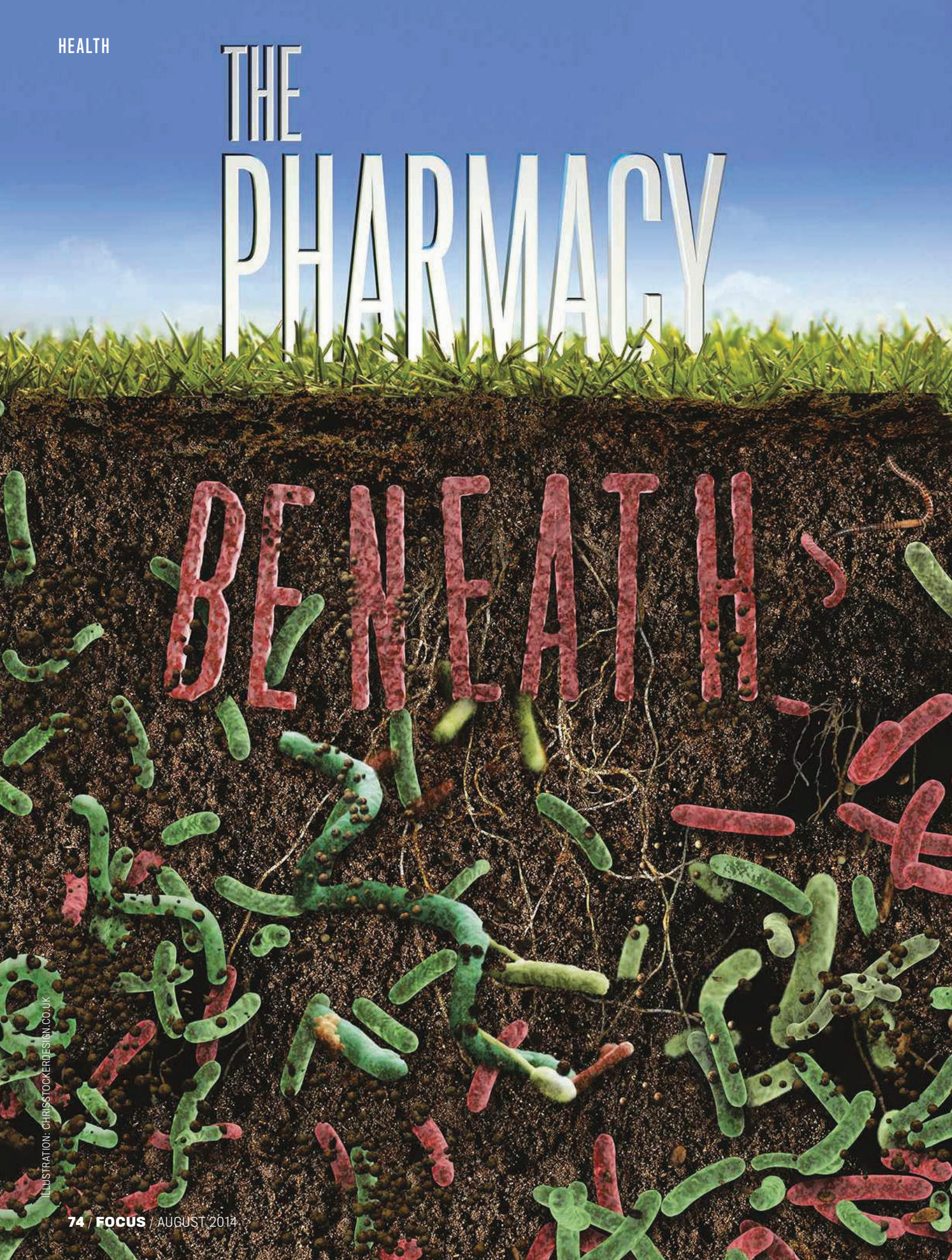
THE PHARMACY BENEATH



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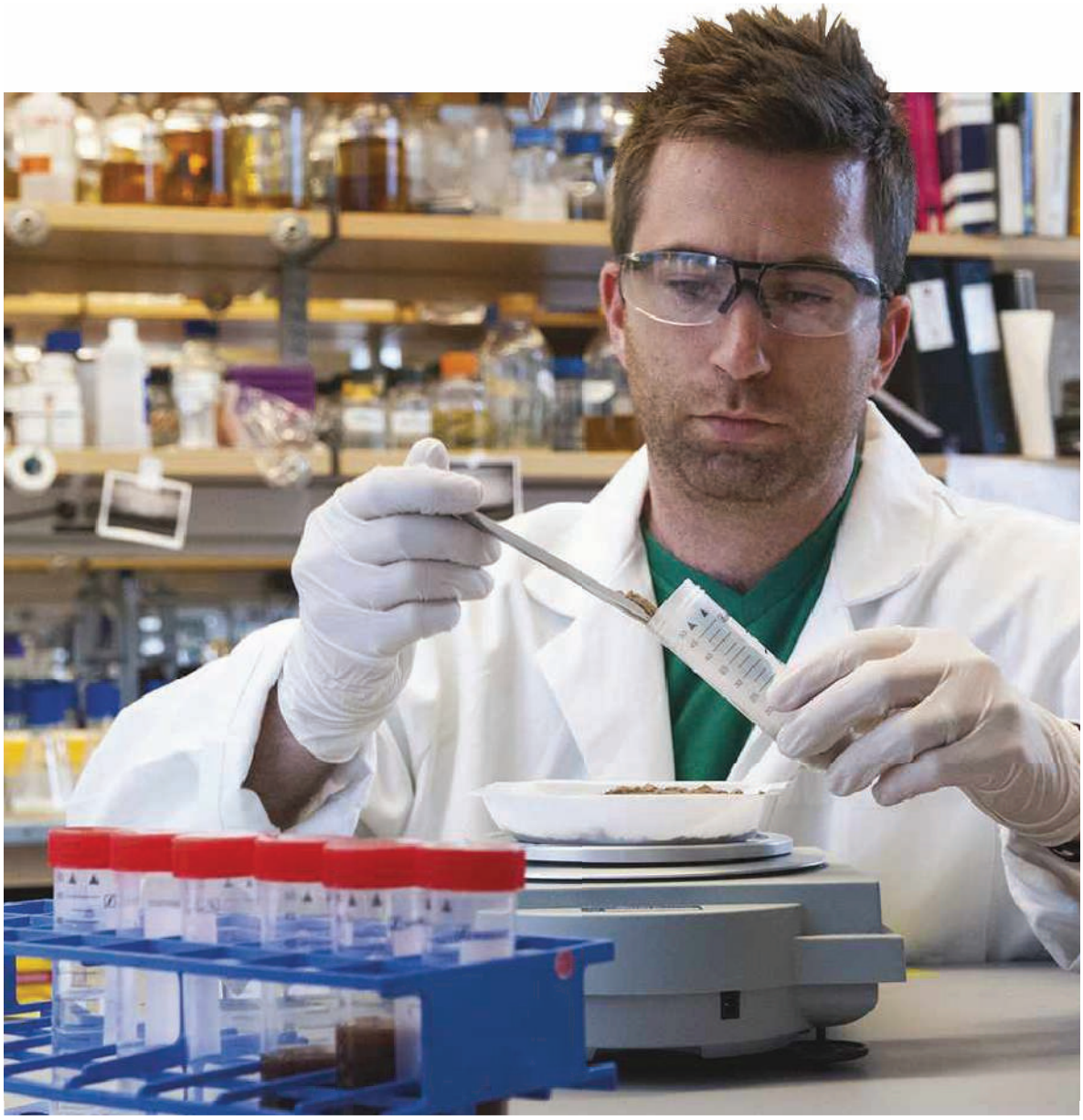
YOUR FEET

With antibiotic resistance spreading, the hunt for new drugs is getting ever more urgent. But as **Zoe Cormier** learns, an answer may lie in the soil

FOR A CENTURY, antibiotics have saved us from diseases that once decimated human populations. In 1850, up to four out of ten children in the UK died before their first birthday, mostly due to diseases we today think of as relics from the past, such as whooping cough (caused by *Bordetella pertussis*), cholera (*Vibrio cholera*), and pneumonia (*Streptococcus pneumoniae*). But today, antibiotic-resistant



A researcher at The Rockefeller University looks for new antibiotics in soil

PHOTO: ROCKEFELLER UNIVERSITY X2, BRIAN C FRANK/EYEVINE, SCIENCE PHOTO LIBRARY X4

bacteria are on the rise. Old foes that we thought we'd defeated are stronger than ever. Drugs that once conquered these deadly bacteria are now worthless. And antibiotics that are effective today could become useless in the future. Already, pneumonia, tuberculosis and other killers are mounting reinforced attacks on our now vulnerable immune systems.

Thankfully, microbiologists are on the hunt for new solutions in our war against deadly infections, and the most powerful drugs may be somewhere you least expect to find them: right beneath your feet. Researchers at New York's Rockefeller University are looking for undiscovered genes in soil bacteria.

So severe is the problem of antibiotic resistance that the World Health Organisation (WHO) has warned that we face a post-antibiotic world, where assurance of relief from bacterial infection is a thing of the past. In April 2014, it declared: "This serious threat is no longer a prediction for the future, it is happening right now in every region of the world and has the potential to affect anyone, of any age, in any country. [This] is now a major threat to public health."

"Bacteria themselves have been the greatest single source of antibiotic drugs"

Most of us probably think of the fungi in mouldy bread – the original source of penicillin – or possibly computer-designed killer molecules as the weapons we use against microbes. But in fact, bacteria themselves have been the greatest single source of antibiotic drugs. The reason is simple: bacteria have been waging war on each other for millions of years. "Nature has been fighting those genes for resistance for millions of years – it's up to us to learn to understand that bacterial language," says Prof Sean Brady, who's leading the Rockefeller team.

Every corner of the globe – from the ocean floor to the inside of your mouth – has been subject to bacterial turf wars. Antibiotics are merely weapons bacteria have used against each other, and the genes for antibiotic resistance are the defences other species have developed in turn. "Pretty much every drug has a

Over-use in farming has fuelled rising antibiotic resistance

Eventually, the hope is to study soil from all over the USA, with the goal of uncovering new antibiotics

natural origin," explains Prof Brady. "The key is to understand how nature fights the battles we fight."

DIG FOR VICTORY

So far the team at Rockefeller have looked at 100 soil samples, but for their research to be truly effective they want to look at as many more as possible to create a map of biosynthetic diversity in soil microbes. To this end they have launched the Drugs From Dirt Project, a citizen science initiative inviting residents from all 50 states of the USA to send samples of their local soil to the lab for analysis.

Antibiotic resistance requires a global scientific war effort, say Jeremy Farrar, head of the biomedical research charity the Wellcome Trust, and Mark Woolhouse, professor of infectious disease epidemiology at Edinburgh

WHAT IS A MICROBE?

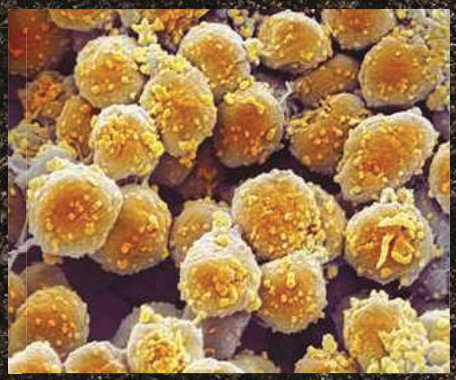
Microbes are very small living things that are invisible to the human eye. They come in countless varieties and can be found everywhere from the upper reaches of the atmosphere to the bottom of the ocean

BACTERIA

This domain of life truly rules the Earth. Bacteria are found on every inch of the planet, down to the ocean floor and within every living thing. For every one human cell in your body there are ten bacterial cells: your gut alone contains a full kilo of bacteria. There are around 50 tonnes of bacteria for every single person on earth.

ARCHAEA

From the Greek for 'ancient things', Archaea were only classified as a separate domain of life from bacteria in 1977. The seemingly simple and ancient microbes were once thought only to be found in extreme environments such as volcanic hot springs and glaciers, but today we know they are found everywhere, including the human belly button.



PROTISTA

With slightly more complex interiors than bacteria, protista are classified in the domain of 'eukaryotes', the group that includes plants, animals and fungi. These single-celled organisms nevertheless resemble bacteria in many ways, including their capacity to cause diseases, such as sleeping sickness and malaria.

FUNGI

Fungi range from the huge networks of mycorrhizal fungi that branch between the roots of trees, to tiny, single-celled microbes such as yeasts, moulds and Penicillium, which produces the antibiotic penicillin. Fungi help plants grow, allow the baking of bread, create antibiotics and poison us with hallucinogens: they are truly microbial mavericks.

University. The pair penned an editorial in the journal *Nature* calling for the creation of the antibiotic equivalent of the Intergovernmental Panel on Climate Change, to manage evidence, catalyse the discovery of new drugs and ensure that coherent policies are adopted worldwide. "Antimicrobial resistance is a global problem that requires global solutions," they wrote. "So far, the international response has been feeble. The World Health Organisation only accepted last month that antimicrobial resistance might fall within the remit of the International Health Regulations."

The problem is due to three factors: our excessive prescription of antibiotics, agricultural waste, and a lack of new drugs. Our overuse of antibiotics has driven the preferential survival of resistant bacteria (see 'How antibiotic resistance works', right). In other words, we have created an evolutionary force driving the spread of drug resistance. Antibiotics do not themselves cause the creation of genes that make bacteria resistant: those traits already occur in microbial populations, and are as ancient as the bacterial species themselves. But antibiotic drugs kill bacteria that are not naturally resistant, leaving the hardy ones behind. These can then reproduce to repopulate a species with drug-resistant genes.

Antibiotics are lifesavers when it comes to bacterial infections, but many people leap to take them when they are not

"Humans can only pass genes to their children, but bacteria can mix and match"

suffering from a bacterial infection at all, but from a virus, such as the common cold or the flu. Taking antibiotics in such circumstances kills benign bacteria that live in your body, further exacerbating the preferential survival of resistant bacteria.

This can then lead to the rise of antibiotic-resistant strains of disease because bacteria can share genes with each other through strange mechanisms such as 'horizontal gene transfer'. Humans can only pass genes to their children, but bacteria can mix and match among themselves. Genes for antibiotic resistance can flow between species, including from benign species to disease-causing ones. Even worse, we are now seeing the rise of 'superbugs' which are resistant to several drugs, having gained resistant genes from a variety of sources.

Another driving factor behind resistance is the increasing use of drugs in agriculture. Though the practice is banned in the EU, in the US antibiotics are used as 'growth promoters' in livestock, fed in bulk to cows and pigs to prevent the spread of disease in crowded pens and speed the growth of the animals. More than half the antibiotics used in America are given to farm animals, encouraging the spread of antibiotic-resistant genes through the environment.

And lastly, in the past quarter of a century there have been almost no new antibiotics discovered. The macrolide, aminoglycoside, fluoroquinolone and tetracycline classes commonly prescribed today were all discovered and approved in the golden age of antibiotic discovery

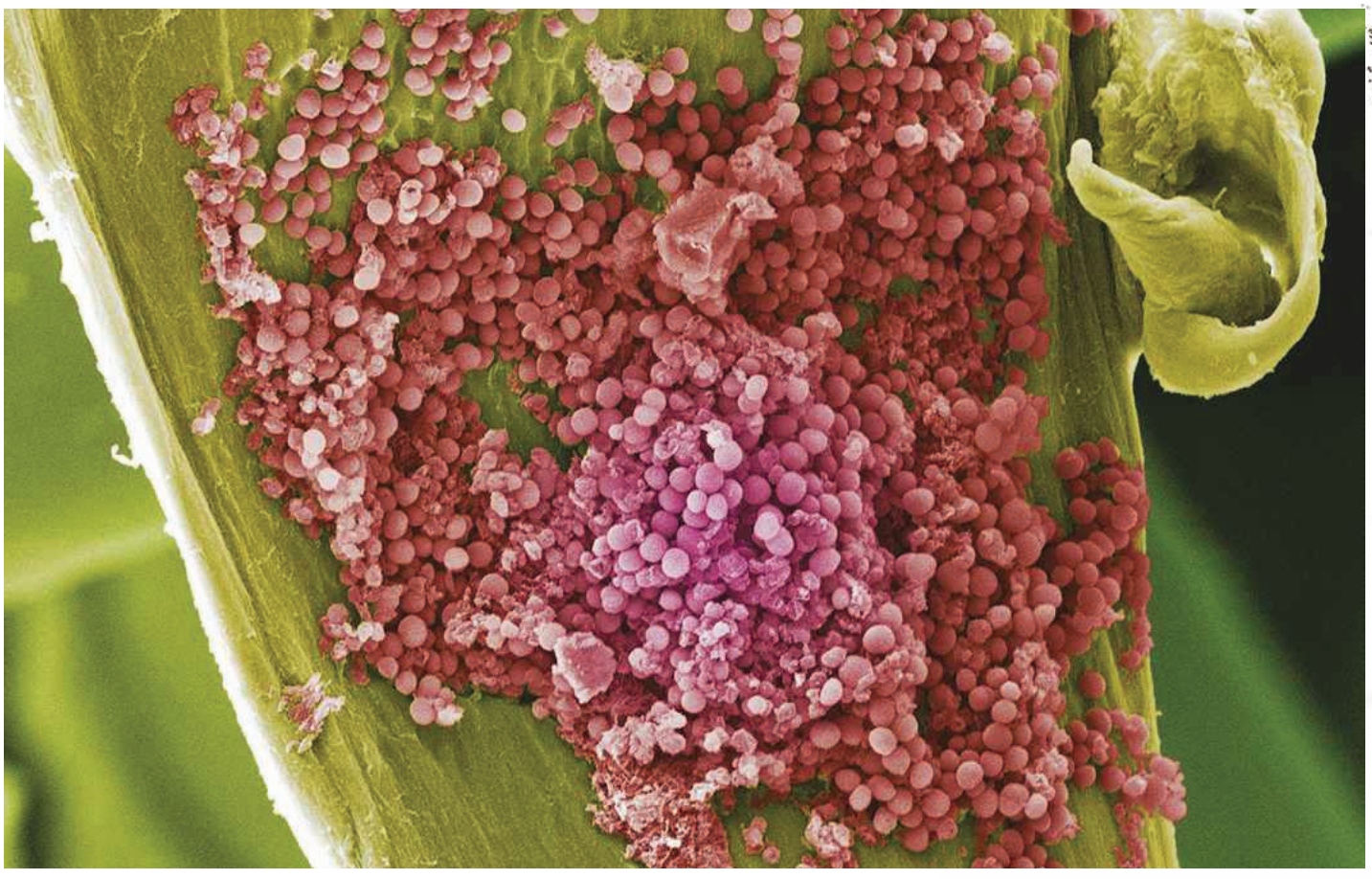
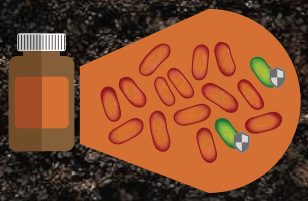


PHOTO: SCIENCE PHOTO LIBRARY X2, CORBIS

***Staphylococcus aureus*, the bacterium that causes MRSA**

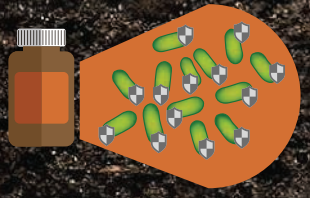
HOW ANTIBIOTIC RESISTANCE WORKS

1 Genes for antibiotic resistance occur naturally in a small percentage of a population of bacteria. But in the absence of an antibiotic, the genes bring no great advantage, so their prevalence remains low.

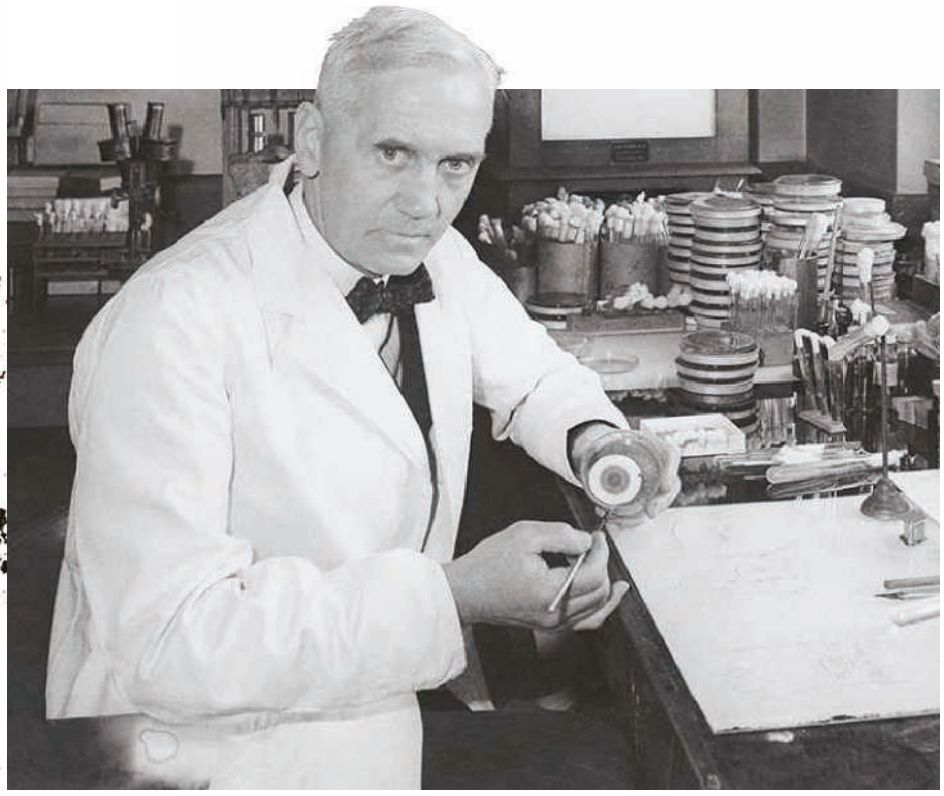


2 The population is exposed to an antibiotic, which kills the majority of bacteria that are not naturally resistant. The resistant bacteria survive, and are left behind when the antibiotic drug is removed.

3 The antibiotic resistant bacteria multiply as they normally would. Because bacteria reproduce so rapidly, this quickly leads to a batch of bacteria where the bulk of the population is antibiotic-resistant.



4 If that population is again exposed to the antibiotic, it will have little effect. A naturally occurring genetic resistance that was once rare is now widespread, and the drug is useless.



Alexander Fleming's discovery of penicillin was one of the greatest breakthroughs in medical history

between 1940 (when industrial manufacture of the drugs commenced) and 1980. Since then, developments have been few and far between. As bacteria marshal their resistance, we have come up with few new weapons to fight them.

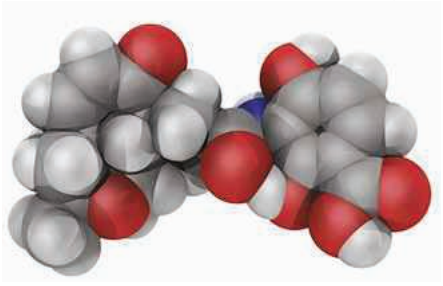
TIME TO GET DIRTY

But though the outlook for antibiotic resistance might seem bleak, the potential for new drug discovery is actually enormous, says Brady, because scientists have so far only looked at a tiny fraction of the bacteria on Earth. "Just the small bit of natural diversity that we have already looked at has saved so many lives – there is a tremendous amount that we have ignored," says Dr Brady. "It's like we've only been looking at what lies in our bedrooms our whole lives, rather than the entire world out there."

What's more, out of the three habitats that globally contain the most bacteria – the ocean, the gut, and soil – dirt by far contains the largest diversity of bacterial species. Soil has already yielded a new antibiotic: platensimycin, isolated from *Streptomyces platensis* by pharmaceutical giant Merck in 2006. This new drug works by interfering with the way bacteria create energy from fatty acids – a new kind of chemistry in antibiotics.

Until now, says Brady, the primary obstacle to looking at a far broader spectrum of genes has been the limitation of only being able to examine strains that can be grown in culture in the lab. Many (possibly most) species of bacteria do not easily grow on simple agar dishes. "There has been a conundrum so far: we could only work on things that would easily grow in the lab," Brady explains. "We have been looking at the bacterial equivalent of weeds."

But with the modern revolution in DNA sequencing, biologists can now look at genetic information, rather than being forced to grow cultures of a microbe before being able to analyse it. So far, they have found that arid soils contain bacteria that can produce a greater diversity of molecules. What else will they find? They aren't sure, but they know they will certainly make new discoveries.



The structure of Platensimycin, the first antibiotic to be discovered as a result of the new focus on soil bacteria

"In every single spoonful of dirt we look at, we find brand new things," says Brady. So maybe the outlook for the fight against diseases isn't quite so bleak after all. ■

ZOE CORMIER is a journalist and science writer specialising in biology and zoology

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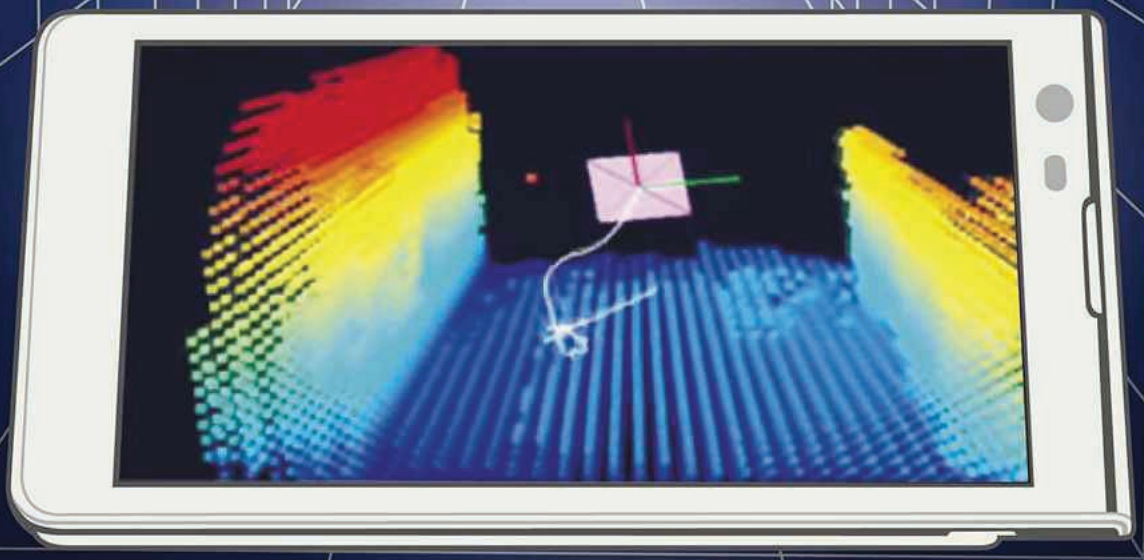


ON THE HORIZON

GOOGLE TANGO

3D mapping system

http://bit.ly/GPTango
(prices TBC)

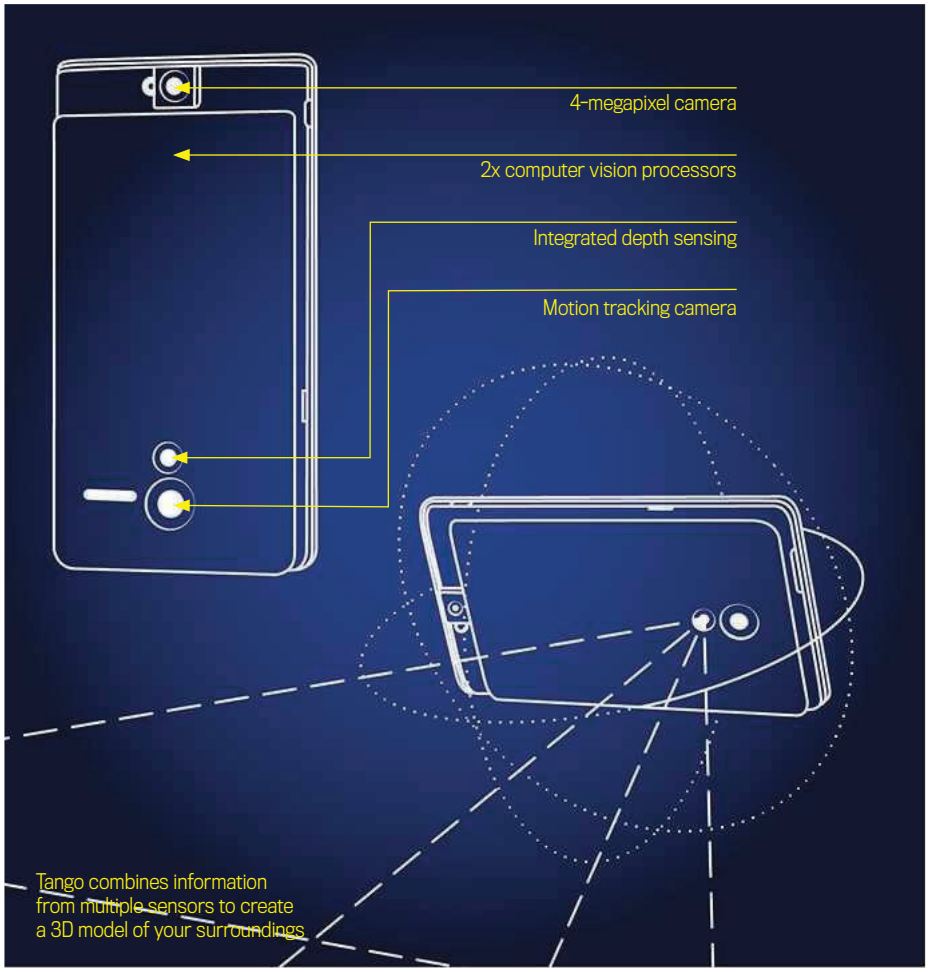
WORDS: **CHRIS HALL**

WHETHER YOU'RE battling with the latest 'intelligent' text-predicting app or losing hair by the handful over yet another so-called 'smart' gadget, the disconnect between technology's promises and our expectations can still be frustratingly wide.

One initiative hoping to bridge the gap between man and machine is Google's Project Tango, which aims to lift the blinkers from the eyes of our smartphones. Big on megapixels but small on angle of vision, the cameras on our mobile devices are incapable of seeing the world as we do. Tango looks to change that, paving the way for apps that have an innate understanding of interior spaces. Tango is essentially a handheld Xbox Kinect scanner on the back of a smartphone (although there's now also a tablet version). Its mission statement is to 'give mobile devices a human-scale understanding of space and motion' by creating 3D maps of the surrounding area.

Project leader Johnny Lee describes the problem. "We are physical beings, that live in a 3D world. But our mobile devices assume the world ends at the boundaries of the screen." It's a project so enticing that Google was able to hire none other than DARPA director Regina Dugan to head up its Advanced Technology and Projects (ATAP) division, which is responsible for Tango.

At Tango's heart are its mobile vision processors. Made by California-based



Tango combines information from multiple sensors to create a 3D model of your surroundings

imaging specialist Movidius, these Myriad 1 chips crunch sensor data before feeding it to the Android software. Tango has a relatively low-resolution 4-megapixel camera, but it's what it does with it that counts. By combining input from the camera, the two vision processors and the depth-sensing, RGB, infrared and motion-tracking sensors, Tango is capable of producing more than 250,000 measurements every second.

The not-inconsiderable task of packing this much computing power into a mobile device, and powering it, is where Movidius' VPU chip comes in. It's a completely custom-built co-processor, which gives it immense power advantages over rivals like Primesense, the company behind the original Kinect technology (which Apple bought last year for a rumoured $350m). Movidius's chips are a breakthrough in that they can generate teraflops of computing power for milliwatts of battery consumption.

Currently, the 3D renders produced by Tango take the form of a depth-scaled heat map, but the resolution will rapidly improve in the next 18 months. Movidius's CEO, Remi El-Ouazzane, says he expects to see this type of technology – albeit not in its fullest form – appearing on the next generation of smartphones.

It doesn't take a great leap of the imagination to see applications for Tango, from planning your interior decor to gaming. Want to know if a new sofa will fit nicely in your living room? Scan it in the showroom, upload it to a saved template of your house, then view it from all angles. Want to take augmented reality gaming to the next level, or perhaps code your own indie game using your own home as a setting? It's easy now. Tango could also be a real boon to visually impaired individuals, enabling them to navigate obstacles via audio instructions.

Tango's potential isn't even limited to this planet. Google has already sent devices to the ISS, mounted on microsatellites called Spheres developed by NASA's Ames Research Center in California. According to Remi El-Ouazzane, the Mars Rover is equipped with similar VPU technology.

CHRIS HALL is a freelance technology journalist and deputy editor of *QP* magazine

ILLUSTRATOR: DEM ILLUSTRATION

TECHOMETER

WHAT'S HOT

ROBOTICS IN THE UK

The UK government's Technology Strategy Board has announced that nearly half of its £400m in research grants this year will be allocated to those working in the fields of robotics and automated systems. Plans include building a test centre for driverless cars in Milton Keynes, and developing autonomous robots to carry out safety checks in nuclear power stations.

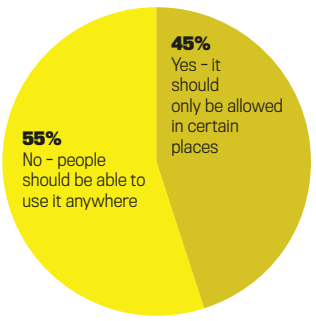
WHAT'S NOT

GOOGLE GLASS

The backlash against wearers of Google's smart specs (we won't use the rather rude nickname) continues. Most recently, the Cinema Exhibitors' Association – the trade body representing 90 per cent of UK cinemas – recommended that its members make Glass 'explorers' remove their headsets, primarily due to concerns about piracy.

READER POLL

Should there be restrictions on wearing Google Glass in public places?



THE NEXT BIG THING

TRUE AI?

Despite much media hype, earlier this year a computer did not pass the Turing test and prove that computers are now 'intelligent'. What really happened was that a chatbot – a program that responds to typed messages – fooled a group of people into thinking that they might be chatting online with a 13-year-old boy from the Ukraine. The attendant publicity did more to expose our anxiety about computers overtaking us in intelligence than it did to reflect the current state of artificial intelligence.

First outlined in 1950 by mathematician and computer scientist Alan Turing, the eponymous test suggests that a computer could be considered intelligent if it can hold a conversation with a human interrogator without being found out. But I've never been convinced that it's a measure of anything useful, and I'm not sure Turing would have approved of the emphasis placed on it in popular coverage of work in AI, because focusing on human conversation ignores innovations in machine learning, image processing and other aspects of cognition.

There's also no reason that 'passing' the Turing Test would require any self-awareness on the part of the software. Whatever the chatbot may have been doing when talking to the judges, nobody has argued it *knew* what it was doing. It was just dumb code. But then we don't need chatbots to be intelligent – we just need them to be useful.

In the days before ubiquitous mobile internet access, British Airways had a telephone number to check flight arrivals, where a pleasant voice would ask for the flight details and then tell you the arrival time. Many users believed it was a human being, but it was all computerised. It could operate effectively because the domain of interest was so limited – if a word sounded like a city on the list, it probably was.

We are going to see more and more cases like this, where our interaction with a computerised system is mediated in a way that feels conversational. It makes sense, because we're much better at human-human interactions than we are at human-computer ones. We see it already in the small group of people muttering 'OK Glass' and asking advice from Siri, but it could go a lot further.

In his film *Her*, Spike Jonze imagines operating systems with personalities so convincing that some people fall in love with the interface – as voiced by Scarlett Johansson. I doubt we'll go that far, but I can imagine a sat-nav system that can make polite conversation being decent company on a long drive across the steppes.

BILL THOMPSON contributes to news.bbc.co.uk and the BBC World Service

COMING SOON

3 MONTHS

PLAYSTATION TV

With this mini-console you can play your PS4 games on any TV in the house, or stream games via PlayStation Now. As for TV/movie streaming, expect similar services to the PS4. *blog.eu.playstation.com*

+ Sigma dp2 Quattro
This is the first camera to feature Sigma's next-generation Flaveon Quattro sensor, which captures luminance as well as colour. *sigmaphoto.com*

+ Apple iWatch
It looks like Apple's smartwatch could land in Q4, with some Far Eastern factories allegedly already producing components. *apple.com*

6 MONTHS

ANDROID AUTO

With 28 auto manufacturers signed up to Google's Open Automotive Alliance, the in-car version of its Android OS looks set to dominate the market. The first cars with Android Auto built-in should appear later this year. *android.com/auto*

+ Ekocycle Cube
Developed by 3D Systems (creative director: will.i.am) and Coca-Cola, this $1,200 (£700) 3D printer makes objects from recycled plastic. *3dsystems.com*

+ Microsoft Surface Mini
The Mini-Me version of Microsoft's tablet failed to appear this summer, but given the iPad Mini's success, it can't be much longer... *microsoft.com*

9 MONTHS

PEPPER

Got a soft spot for Brian, the robot on those car insurance ads? This humanoid robot will be available in Japan early next year – after a stint working in SoftBank phone shops. *aldebaran.com*

+ Google Ara
Google's modular Ara phones, as previewed in the July issue of *Focus*, could reach stores as early as Q1 2015. *projectara.com*

+ Steam machines
With Valve's Steam OS scheduled for release in December, expect to see the first Steam-powered consoles on sale in Q1 next year. *valvesoftware.com*

JUST LANDED: NETATMO JUNE

SOLAR SYSTEM

How much sunshine is too much? Joe Minihane catches some rays to test a new UV-monitoring wristband that tells you

What is it?
Netatmo's June bracelet measures UV exposure and utilises information about your skin to tell you how much sun you're getting, when to apply sunscreen and when it's time to get out of those damaging rays.

How does it work?
June uses Bluetooth to link up with an iPhone app. Download it from the App Store and it'll ask you for key information about your eye and hair colour, skin tone and how your skin reacts to the sun. The app then uses these details to work out your skin type, from one to six on the World Health Organisation's Fitzpatrick scale. The bracelet unit then begins detecting the full spectrum of both UVA and UVB rays, working out your daily 'Sun Dose'. This uses the WHO's Minimal Erythema Dose, which works out when each skin type will start to burn, given the UV levels at that moment. June will then tell you via a notification when to slap on sun cream or get out of the sun.

How seamless is the connection?
Theoretically, June should sync with your iPhone without any hassle. In reality, this is not the case. We went through the setup process only to be told by the app to fire up Bluetooth, despite it already being on. Hitting the 'retry' button didn't help matters and it remained stuck in setup mode. We got around this by logging out, re-entering our details and pairing while the June was in its docking station. Hardly breezy.

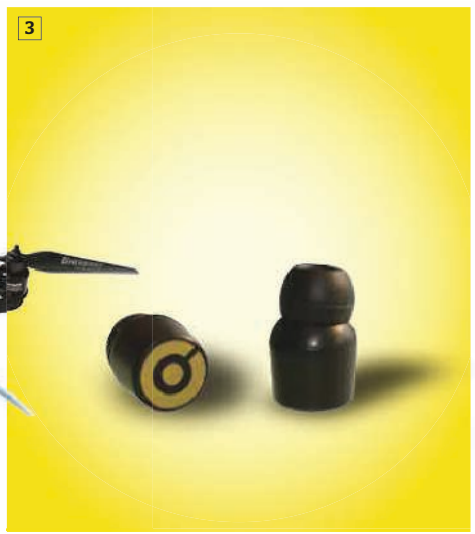
Is it useful?
Absolutely. After an hour in the sun, we were alerted to reapply SPF 30, something we would usually have left a lot longer. The warnings about the sun's growing intensity come in seriously handy, especially as it's easy to ignore the signs and stay in direct sunlight for longer than is safe. Worryingly, a recent Cancer Research UK study found SPF 50 was still not enough to prevent cancerous melanomas, with over 100,000 cases diagnosed in the UK each year. However, the app only ever recommends one type of SPF depending on your skin, not when to use a higher factor when the sun gets stronger. Covering up, something which June also advocates via notifications, is more important than sticking on more sun block.

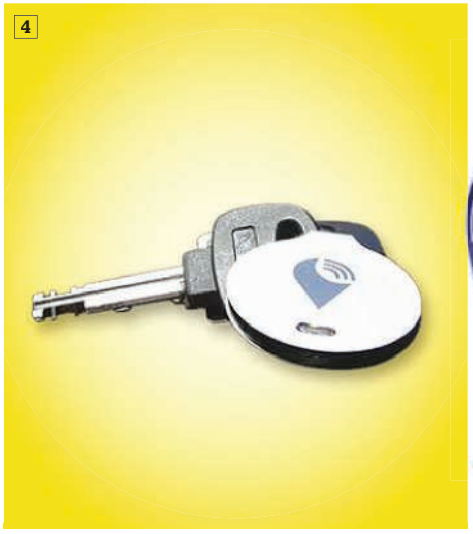
Does it work on other platforms?
Unfortunately not. June only plays nicely with iOS – Android and Windows Phone users have been left out in the cold. Netatmo has not yet said whether it plans to release a version of the app for these operating systems in the future.

Should I buy one?
The concept is very smart and the information it offers is extremely valuable, considering how dangerous unchecked exposure to the Sun can be. It looks like a proper piece of jewellery, offering a great alternative to the tech-focused looks of other wearables on the market. However, the app is poorly designed and hard to use, while its Bluetooth struggles are a major concern. Until the app is updated, it's best to keep your credit card in your wallet.

Netatmo June
£69, www.netatmo.com

JOE MINIHANE is a technology and travel journalist





APPLIANCES OF SCIENCE

1 NEW MUG IS NO MUG

If you take fitness seriously, monitoring your intake of fat, sugar and calories, your hydration levels and how much caffeine you're consuming is a must. That task just got easier with arrival of Vessyl, a sensor-equipped 'smart cup' from San Francisco-based Mark One that gathers all that data and relays it to the Vessyl iOS/Android app. It's available to preorder now for half the final retail price.

Vessyl
myvessyl.com, $99 (£59, pre-order only) plus P&P

2 IT'S BEHIND YOU!

Helmet-mounted cameras are great for *Peep Show*-style footage of your extreme sports antics, but what about the bigger picture? This miniature drone from US start-up Hexoplus links wirelessly to your smartphone, following your every move and recording a bird's-eye view of your exploits on an attached camera. It's available on its own or bundled with a GoPro camera and gimbal, and will ship in May 2015.

Hexo+
hexoplus.com, $599/$799 (£353/£470) plus P&P

3 BEST BUDS

What you see here are the first truly wireless in-ear buds. 'Truly wireless' because not only do they not require a cable to connect them to your phone or mp3 player, unlike other 'wireless' systems no cable connects the two buds, either – which means they can be made smaller. The two discrete buds link to your music-playing device of choice using Bluetooth, and charge from a tubular case that also keeps them safe in your pocket when you're not using them.

Earin
earin.se, £159

4 TWO-WAY TRACKER

Tracking devices that attach to your wallet, car keys or other eminently misplaceable possessions are nothing new. What's different about TrackR bravo, though, is that the system works both ways: if you lose your keys you can locate them using your smartphone, or if you can't find your phone you can call it by pressing a button on the bravo. It's also said to be the thinnest such device currently available.

TrackR bravo
thetrackr.com/bravo, $29 (£17) plus P&P

5 DIY TOYS

Parents are forever telling their children that "we made our own fun in those days". Well, now your kids can make their own fun too, with Printeer – the first 3D printer aimed at children. Currently racing towards its funding target on Kickstarter, Printeer comes accompanied by a simple, child-friendly iPad toy-design app, has visible, colourful moving parts and can print objects measuring up to 127x127x100mm.

Printeer
printeer.com, $549 (£325) plus P&P

6 WRIST PROTECTOR

Designed for women but wearable by either sex, Safelet is a personal security bracelet that pairs with an iOS/Android app. Should you feel threatened, you press the Safelet's two buttons (on one each side) and it will send a message to your selected 'guardians' (friends, family or the police) with your precise location, and activate the built-in microphone. You can even opt to have such recordings relayed straight to the authorities.

Safelet
safelet.com, $99 (£72, pre-order only) plus P&P

ULTIMATE TEST

BLUETOOTH BOOMBOXES

JOE SVETLIK is a freelance technology journalist and news reporter

It's summer, so fire up the barbie and pump up the volume! But which wireless speaker is for you? Joe Svetlik reviews some of the best models for both indoor and outdoor use

PHOTO: THESECRETSTUDIO.NET

On test: Sonos Play, Dali Kubik Free/Extra, Pure Jongo T4, Philips Fidelio E2, Spaced360, B&O Beolit, Braven BRV-1, Monster Superstar

1 SONOS PLAY

SET-UP IS SIMPLE, but takes a few minutes if you have a few speakers. To do this just plug the 'Bridge' connector into your wireless router, and press and release the buttons on each speaker to add them to the network. Fire up the Sonos mobile app and you can control it from your phone, or use the dedicated controller or desktop software. Grouping speakers is a doddle, as is splitting them into different zones (perfect for a house party). It's a cinch to add services like Deezer and Spotify, too. Sound quality is very good, but it's pricey if you want a speaker in every room.

£169–£349; £39 (Bridge)
sonos.com

2 DALI KUBIK FREE AND KUBIK EXTRA

IF IT'S SLEEK Danish design you want, this is the system for you. Use the Kubik Free on its own, or add Kubik Extra for stereo, or to create a two-room system. You can choose from nine different cover colours and you can tweak the sound depending on how your system is configured, too. The sound they produce is full and rich, and you can plug in a TV or a computer using the USB, Toslink and RCA inputs. If money is no object, add another star.

£645 (Kubik Free); £899 (Free plus Extra)
dali-speakers.com

3 PURE JONGO T4

THESE SPEAKERS FEATURE Pure's new Caskeid streaming technology, which claims to offer higher-quality streaming than standard Bluetooth. You can pair multiple Jongos to make a multiroom system, with different music in each room, and unlike the rival Sonos system, you can do this with any music app, not just Spotify. The sound packs plenty of punch, but lacks some clarity. You can wall-mount the speakers, put them on a stand or leave them as standalones, and the grilles come in a huge range of colours. Set-up is simple, too. A fantastic all-rounder at a competitive price.

£199.99
pure.com

FOCUS BEST BUY

4 PHILIPS FIDELIO E2

THESE FEATURE NFC – tap your phone against the panel on the side, and you can play music through them. Or you can pair over Bluetooth. You can hook up a TV and games console as well, using the optical, coaxial and HDMI connections. One of the wooden tops houses the controls, so press it to change the volume and to power it up. The remote is packed with options too, including bass and treble. But the design is a little drab, and the sound isn't quite as room-filling as some others on test.

£300
philips.co.uk

PHOTO: THESECRETSTUDIO.NET

5 SPACED360

THANKS TO ITS patented AirSOUND technology, this speaker throws out music in every direction, so it'll sound the same wherever you are in relation to it. And it works: walk around the speaker, and it sounds identical the whole way. The rubber sleeve is a bit of an effort to get on (it feels like yanking on a wetsuit), but it keeps the speaker safe from knocks and bumps, and the yellow and orange options add a nice touch of colour. Charging it up is a doddle – just plonk it on the dock – as is pairing via Bluetooth or NFC. A great addition to campfire singalongs.

£250
spaced360.com

FOCUS BEST BUY

6 B&O BEOLIT 12

AS YOU'D EXPECT from B&O, the Beolit 12 has some serious design cred: from the leather carry handle and capacitive buttons on the top to the compartment for stowing the charging cable, this thing oozes class. When it comes to usability, however, things start to come unstuck. It works with Apple's AirPlay, but that's it: there's no Bluetooth or NFC, so if you're using Android or Windows Phone, you'll have to plug your mobile into the speaker. Sound is full and rich, but we can't forgive the lack of versatility. For this price, you should get your own band thrown in.

£599
beoplay.com

7 BRAVEN BRV-1

THIS THING IS built like a tank. With its rubberised case, it feels like it can take anything you can throw at it. It's splashproof, too, although it won't survive a dunk in the drink, so don't get too carried away. You can pair two BRV-1s and listen in stereo, plus there's a switch for outdoor and indoor modes: in Indoor mode, the sound is a bit more intimate and less dispersed, but still fills a room easily. Sound is as big and bold as the design suggests, and pairing is a doddle over Bluetooth or NFC. There's even a handy carry case thrown in. A very respectable budget offering.

£199
braven.eu

8 MONSTER SUPERSTAR

IT MAY BE small, but don't underestimate this speaker. It's very loud indeed, thanks to two full-range drivers and two central bass radiators. Sound quality is very good considering it's coming from a package about the size of a smartphone, though there is some distortion at louder volumes. The blue model we tested was bright and easy to find in a bag, and it's splashproof and feels hard-wearing too. There's no NFC, so you'll have to Bluetooth it, but for the smallest and cheapest speaker on test, we're impressed.

£99.95
monsterproducts.com

THE LENGTH OF ONE METRE

BY ANDREW ROBINSON

Defining the length of a metre meant a revolution in accurate scientific measurement. From metal bars to spectrums of light to today's laser-based system, discover how pioneers rewrote the rules

THE EARLIEST UNITS for measuring length were based on the human body – most obviously the arm and the foot – and on seeds and grains. An Ancient Greek relief sculpture dated to about 450BC, kept at the Ashmolean Museum in Oxford, shows a male figure with two arms stretched out and a foot-shaped depression above one of the arms. The sculpture may have been set up in a public place as a set of standard measurements. If its damaged arm is completed by symmetry, then the full arm span, known as the fathom, measures 2.08 metres (m); the forearm, known as the cubit, 0.52m; and the foot 0.297m.

In the Roman Empire, the *milliare* gave its name to the mile, a length of 1,760 yards (1,609m). The milliare equalled *mille passuum*, a 'thousand paces' of a length taken by a Roman legionary on a long march. This makes a 'pace' about 1.6m – clearly an impossible average length for walking. The Roman 'pace' must therefore refer to the full cycle of left-right-left or right-left-right, giving a reasonable single pace of about 0.8m.

In Medieval England, the barleycorn defined the inch, the foot and the yard. During the reign of Edward II, in the 14th Century, the inch was defined as 'three grains of barley, dry and round, placed end to end, lengthwise'. For smaller lengths, the barleycorn was split into four equal parts, to create the line. So there were 12 lines in an inch, 12 inches (and 36 barleycorns) in a foot, and three feet in a yard.

In France, before the 1789 Revolution paved the way for the introduction of the metric system, a staggering 250,000 measures were in use under the guise of some 800 names, including the *aune* for length. Since the time of Charlemagne, eight French kings – including Louis XIV, the 'Sun King' – had attempted to lay down the law regarding standard weights and measures. All failed, because uniformity did not please the feudal aristocracy, who habitually manipulated the diversity of customary units to the disadvantage of their peasantry.

Inconsistency particularly bedevilled the cubit, a unit approximately equal to the distance from a man's

This Ancient Greek relief from 450BC shows an early attempt at standardising measurement

PHOTO: NPL, ASHMOLEAN MUSEUM OXFORD

The Length Bar Interferometer at the National Physical Laboratory uses laser light to define a given length up to a metre

> IN A NUTSHELL

From early forms of defining length with seeds and parts of the body, to defining a length based on accurate measurements of the size and shape of the Earth, it's taken hundreds of years for a standard metre to be used throughout the world.

elbow joint to the farthest fingertip of his extended hand, or about half a metre. In ancient Egypt, the short cubit equalled six palms, while the royal cubit (used in the construction of the Pyramids) equalled seven palms. The eight different cubits known in the early civilisations vary in length from Roman 0.444m to Palestinian 0.641m.

Clearly a measurement of length defined by a universally agreed standard was needed, especially for international trade. The Greek mathematician and geographer Eratosthenes, who became director of the library at Alexandria in 235BC, was the first to attempt such a definition by determining the Earth's circumference using astronomy and geometry.

Eratosthenes employed a well in far-off Syene (modern Aswan) and a vertical obelisk in the grounds of the Alexandria library. On the day when the overhead Sun shone directly into the well, casting no shadow on its walls – that is, the summer solstice – Eratosthenes, further north in Alexandria, measured the angle created between the obelisk and its shadow. Since Syene and Alexandria lay almost on the same meridian of longitude, this angle measured the difference in latitude between Syene and Alexandria.

If the Earth were a perfect sphere, the angle at the Earth's centre subtended by the well and the obelisk – by definition the difference in their latitudes – had to equal the angle of the shadow, from simple geometry. (This assumed, reasonably, that the Sun was so far away that all its rays were parallel at the Earth.) The angle was 7.2°. Given the distance by camel from Alexandria to Syene, known to be about 5,000 *stadia*, the circumference of the Earth (subtending 360°) could be calculated. Multiply 5,000 by the ratio 360:7.2 and you get 250,000 stadia. The length of the stadium is unfortunately disputed, but one modern conversion of 250,000 stadia would give 39,690km (24,662 miles) – very close to the current value of Earth's equatorial circumference, 40,075km (24,901 miles).

TRUSTED TRIANGULATION

As the Earth's geography became clearer through the great sailing voyages of the 16th Century, so did the accuracy of surveying techniques on land. Triangulation was first reported in a book published in Antwerp in 1533. In the 17th Century came telescopes with cross-hairs for sighting the stations being triangulated. These were introduced in the 1670s in France, the earliest country to attempt an exact survey of itself, under the direction of Jean-Dominique Cassini, the first of four generations of Cassini surveyors of France. The survey shifted the western coastline of existing maps about one-and-a-half degrees of longitude east in

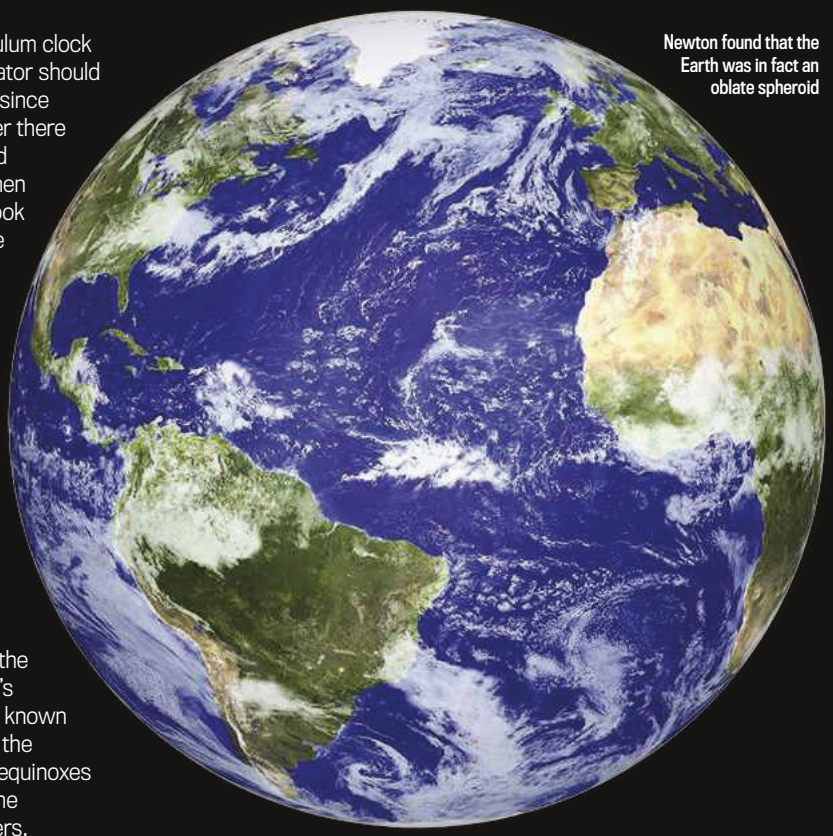
THE KEY DISCOVERY

Isaac Newton's theory of gravity predicted the true shape of the Earth, and therefore the varying length of a degree of latitude. It would prove a crucial step in defining the metre

NEWTON USED THE trigonometrical survey of the Paris meridian in his calculation of the force of gravity. His theory led him to predict, in his *Principia Mathematica* of 1687, that the Earth could not be a perfect sphere. Centrifugal force, caused by axial spinning, was balanced by gravitational force. But since the equator moved faster than the poles, the equator must bulge very slightly, while the poles must be slightly flattened, resulting in an oblate spheroid like a flattened tomato. Gravitational attraction at the equator must be slightly less than at the poles, since gravity weakens with distance from the centre of the Earth.

To prove this, Newton first re-analysed the French survey data to show that a degree of latitude appeared to lengthen slightly as one moved north – an increase to be expected from a bulging equator and flattened poles. Second, he noted that a pendulum clock carried to the equator should beat slightly slow, since gravity was weaker there – which had indeed been observed when a French savant took such a clock to the Caribbean in 1672. Third, he pointed out that astronomers had observed Jupiter to be flattened at the poles.

Finally, he showed how the gravitational pull of the Sun and the Moon on a bulging equator could account for the swivel in the Earth's axis that had been known to be the cause of the precession of the equinoxes since the time of the ancient astronomers.



Newton found that the Earth was in fact an oblate spheroid

PHOTO: ALAMY X2, THINKSTOCK X2, AKG IMAGES, NASA

relation to the Paris meridian, and the southern coastline about half a degree of latitude to the north. Brest moved 177km (110 miles), Marseilles 64km (40 miles). When in 1682 Louis XIV paid a visit to the Paris Observatory and saw the new map, he exclaimed to Cassini: "Your journey has cost me a major portion of my realm!"

The French survey data also adjusted the shape of the Earth: from the perfect sphere imagined by Eratosthenes to a prolate spheroid: that is, a sphere slightly flattened at the equator and slightly bulging at the poles. But Isaac Newton, working across the English Channel, disagreed with Cassini (see 'The Key Discovery'). Newton calculated an oblate Earth, bulging at the equator and flattened at the poles. Not until the 1730s-40s, after Newton's death, was the question resolved in Newton's favour. Two gruelling expeditions led by French savants measured a degree of latitude in Lapland, near the pole, and in Peru, at the equator. The results were conclusive enough, said the French writer Voltaire – a devotee of Newton – "to flatten both the poles and the Cassinis".

THE FRENCH CONNECTION

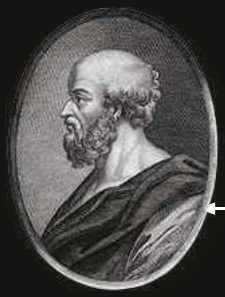
The very first proposal to relate all length measurements to a decimal system based on the Earth's dimensions came from a French churchman, the Abbé Gabriel Mouton, writing in 1670. He suggested that the primary length unit should equal 1 minute of arc of a great circle (ie the circumference) of the Earth, a length not far short of 2,000m. But instead, a standard length based on the length of a pendulum was considered.

By the late 18th Century, scientists were aware that the rate of swing of a pendulum depended not at all on the weight of the bob, only on the length of the pendulum. Its period could therefore be used to define length. In fact, the so-called seconds pendulum, swinging once every second, has a length of 0.994m at sea level and latitude 45°, halfway between the equator and the poles, under conditions of standard gravity.

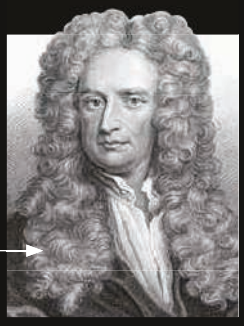
However, the pendulum measurement of the metre was rejected, partly because the period depended on gravity, which was known to vary with altitude and latitude, and partly because the units of time were themselves

CAST OF CHARACTERS

From an Ancient Greek to a French emperor, it's taken an eclectic mix to standardise measurement



Eratosthenes (c. 276BC - c. 195/194BC) was a Greek mathematician, astronomer and geographer, as well as a poet and music theorist, who became director of the library at Alexandria in 235BC. He is principally known for his accurate calculation of the circumference of the Earth and his map of the world based on parallels and meridians.



Isaac Newton (1642-1727), the son of an English yeoman farmer who needs no introduction as a mathematician and physicist, also studied alchemy and religion. Although he never left the shores of England, he took a keen interest in calculating the shape of the Earth from both survey data and gravitational theory.

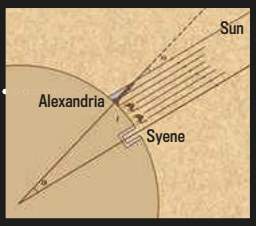
Pierre François André Méchain (1744-1804), a French astronomer and hydrographer, he surveyed the southern part of the meridian arc from Dunkirk to Barcelona during the 1790s in collaboration with Jean Baptiste Joseph Delambre. Director of the Paris Observatory from 1799, Méchain died in Spain while checking his survey, which was completed by François Arago in 1806-09.

Jean Baptiste Joseph Delambre (1749-1822), a French astronomer, he surveyed the northern part of the meridian arc from Dunkirk to Barcelona in collaboration with Méchain. After the death of Méchain, Delambre became director of the Paris Observatory and published three volumes defining the basis of the metric system in 1806-10.

Napoléon Bonaparte (1769-1821) strongly encouraged the development of science in France. This began with his invasion of Egypt in 1798, accompanied by a party of scientific savants, and continued after he proclaimed himself emperor in 1804. Although he was a leading supporter of the new metric system, he personally refused to use it.

TIMELINE

Becoming ever more accurate, there have been many methods of defining length over the centuries

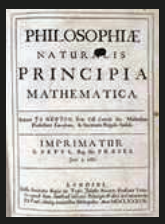


3RD CENTURY BC

Eratosthenes, from measurements of the Sun's shadow in Alexandria and Syene, calculates Earth's circumference as 250,000 *stadia*, approximately 39,690km –very close to the current value of Earth's equatorial circumference, 40,075km.

1687

Isaac Newton, in his *Principia Mathematica*, proposes that Earth is not perfectly spherical. It is an oblate spheroid, flattened at the poles, bulging at the equator. An equatorial degree of latitude is slightly shorter than a polar degree.


PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA
IMPRIMATUR

1792–99

Two astronomers, Jean Baptiste Joseph Delambre and Pierre François André Méchain, measure the meridian arc from Dunkirk to Barcelona, which serves to fix the length of the metre.

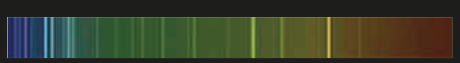
1801

The metric system is imposed in France by Napoléon Bonaparte. All measures, except hours, minutes and seconds, are decimalised. However, conflict with pre-metric systems causes its partial withdrawal in 1812.

1875

In Paris, representatives of 17 nations and empires sign the Convention Of The Metre, 'desiring international uniformity and precision in standards of weight and measure'. Britain signs in 1884.

1960



The Système International d'Unités, generally known as the SI system, is established. It consists of seven basic units, including the metre, kilogram and second. The metre is redefined in terms of a spectrum line of krypton, and later in terms of the speed of light.

under Revolutionary review. The unit of length finally selected by the French Academy of Sciences in 1791 was one ten-millionth of a quarter of a great circle, in other words one ten-millionth of the distance from the equator to the North Pole (assuming the Earth to be spherical). Since the circumference of the Earth was 40,075km (24,901 miles), a quarter was just under 10,019km. Dividing this figure by 10 million gave just over 1m.

In 1792, two French scientists, Jean Baptiste Joseph Delambre and Pierre François André Méchain, set out to measure the length of the Paris meridian from Dunkirk to Barcelona by triangulation; the latitudes of Dunkirk and Barcelona were figured by astronomical observations. This challenging task, conducted at a time of political turmoil in France and war between France and Spain, took more than seven years to complete, ending in the death of Méchain.

Its accuracy was formidable. Even so errors crept in because of the oblate Earth, instrument error and human error in making endless finicky observations. But the great scientific expedition did give legitimacy to the metre and prestige to the metric system, which was officially imposed on France by Napoléon Bonaparte's government in 1801. For all its initial unpopularity, metrication was inevitable in the long run. As Napoléon farsightedly congratulated Delambre in 1806: "Conquests will come and go, but this work will endure."

GOING GLOBAL

For a century and a half, until the introduction of the Système International (SI) in 1960, the survey-based metre was embodied in the length of a metal bar kept in a vault at the International Bureau of Weights and Measures in Sèvres near Paris, copies of which had been distributed to national standards institutions in other countries.

In 1889, a new prototype bar was made from a dense platinum-iridium alloy. It had an X-like cross-section intended to minimise sag and distortion when the bar was properly supported. On the polished facets at both ends, there were fine horizontal graticules, lines made for visual settings by micrometer, and thicker vertical lines to monitor the expansion of the metal in the temperature range

PHOTO: ALAMY X2, MARY EVANS PICTURE LIBRARY, WIKIPEDIA X2

A standard metre from the late 18th Century in Paris. People would bring their metre rulers and place them within this standard to see if they were accurate

NEED TO KNOW

These terms will help you understand the story of the metre

1 MERIDIANS

Circles of constant longitude, passing through a given place and through the terrestrial poles. The French meridian passing through Paris was used to define the metre, while the British meridian passing through Greenwich still defines the world's time zones.

2 OBLATE/PROLATE SPHEROID

An oblate spheroid is a sphere that is flattened at the poles, bulging at the equator, like a tomato. A prolate spheroid, by contrast, is elongated at the poles, flattened at the equator, like a lemon. Earth is an oblate spheroid, as first demonstrated by Isaac Newton.

3 TRIANGULATION

Triangular surveying proceeds by building up a chain of interlinked triangles. The first triangle is constructed from a precisely measured horizontal baseline. Its two base angles are measured through sighting instruments aimed at a prominent landmark – the triangle's third vertex. These angles are then used to calculate the lengths of the triangle's other two sides by simple trigonometry, after allowing for any altitude difference between the vertex and the baseline.

0-20°C. The standard length was always measured at 0°.

The disadvantages are obvious, and during the first half of the 20th Century scientists made progressive attempts to find techniques to redefine the metre in terms of the wavelength of light – an invariable standard that could be measured in any laboratory with the right equipment. In 1960, the metre was redefined in terms of a spectrum line of krypton. Then in 1983, the current definition was adopted, based on the speed of laser light. The metre is now the length of the path travelled by light in vacuum during a time of 1/299,792,458 second.

A METRIC WORLD

After France, the next countries to metricate were its neighbours, which had come under direct French rule. Spain went metric in the 1850s, followed by Germany and Italy as part of their political unifications. In 1875, 17 nations and their empires signed the Convention Of The Metre. By 1900, well over half of European nations had gone metric. The first Asian nation to convert was Mongolia in 1918. Before this, Japan and China had both shown interest, but neither nation moved until the 1920s. In Japan, there was popular opposition and conversion was shelved until the 1950s; in China, metrication did not revive until 1959, 10 years after the Communist Revolution. Political upheaval promoted metrication, as it had in France, Italy, Germany and the Soviet Union, which metricated in 1924 after the Russian Revolution.

Britain officially committed itself in 1965, then dragged its feet and abolished the Metrication Board in 1979. Since 1974, the metric system has been taught in British schools and metric packaging has been gradually introduced alongside imperial. But there is no plan to convert road signs. As for the United States, there is little political will to metricate. Even in science, the old measures are sometimes used alongside the metric system – as became embarrassingly obvious in 1999 when a NASA probe sent to Mars was lost because one of its design teams had used the traditional units while the other had used metric.

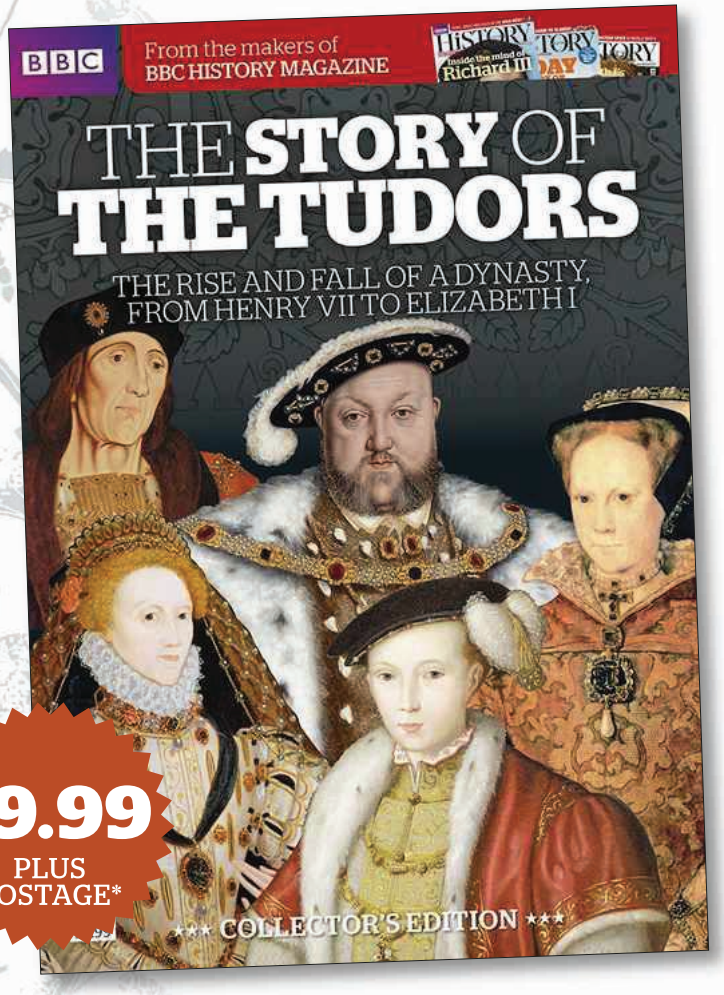
Since 1791, when the metre was measured as one ten-millionth of the quarter meridian of the Earth to within 0.06mm, scientists have made drastic strides in accuracy. When you're told the length of something in metres, you can be confident that we now know the length of a metre to within 0.00000002mm, or one-hundredth of the width of DNA's double helix. ■

Andrew Robinson is the author of *The Story Of Measurement* (Thames & Hudson)

Find out more

BBC FOUR Watch Marcus du Sautoy explain the quest to measure the metre in *Time And Distance*
http://youtu.be/x1DT8flqqZAc

THE STORY OF THE TUDORS



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The Tudor period remains one of the most fascinating eras in English history. This new special edition examines the reign of each Tudor monarch, from Henry VII's victory at the battle of Bosworth in 1485 right through to Elizabeth I's death in 1603, upon which the House of Stuart took the throne.

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TO DO LIST

WATCH
LISTEN
TOUCH
VISIT
READ

PLAN YOUR MONTH AHEAD WITH OUR EXPERT GUIDE

PICK OF THE MONTH

You'll find the Survivaball suit at the exhibition; it could save your life when sea levels rise... probably

STRANGE WEATHER

WHEN IT COMES to striking up small talk with strangers, there's usually only one acceptable topic of conversation in Britain: the weather. Whether we're in a bus queue or the hairdressers, most of us can't resist commenting on the state of the skies overhead. But recently, there's been even more to talk about. Last winter was the UK's soggiest since records began in 1910, leaving the Somerset Levels stricken by floods and Cornwall without railway access to the rest of the country.

So what's going on with our weather? Are the recent happenings part of our planet's natural variability, or a sign of things to come? And if our weather is getting weirder, should we be trying to prevent it or live alongside it? To explore some of these questions, Dublin's Science Gallery has brought together meteorologists, artists, climate scientists, cloud enthusiasts and designers for a brand new exhibition: Strange Weather.

There's plenty to get your hands on. You can put yourself in the shoes of the experts and play around with a state-of-the-art climate model, use a green screen studio to present a weather forecast from the future, or have a go at predicting the weather yourself, pitting your wits against professional meteorologists from Met Éireann, Ireland's National Meteorological Service.

Elsewhere, there's a selection of exhibits designed to reveal everyday weather in a new light. There's a machine that suspends a single raindrop in mid-air, a poetry anthology fashioned out of Tumblr blog posts, and an installation in which participants play God, manipulating clouds as they drift across a giant fabric screen.

For those who fancy something a little more out-there, there's also the chance to eat a cloud – yes, eat a cloud – that's been captured from the atmosphere by a device called the Cloud Collector. What happens when you feast on a cloud? Will you float to the sky? Will you unleash a downpour of epic proportions? Probably not, but at least it'll give you something to tell your neighbour.

JAMES LLOYD

Strange Weather is at Dublin's Science Gallery until 5 October; free; for more info see dublin.sciencegallery.com

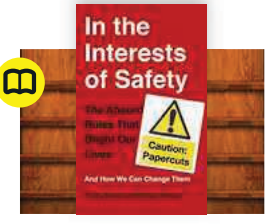
DON'T MISS!

Skyscraper High

Find out how New York's One World Trade Center, a marvel of engineering, has risen from the ashes of the Twin Towers. p100

Edinburgh Fringe Festival

You'll find some hilarious science events at the world-famous comedy festival this month. p103



In The Interests Of Safety

'Elf and safety is rampant, but is it all necessary? Find out in this new book. p104

PHOTO: THE YES MEN

WATCH

TV, DVD, BLU-RAY & ONLINE

WITH TIMANDRA HARKNESS

27 JULY

Comet Impact

Quest, 9pm

LANDING A SPACECRAFT on a comet is no mean feat. When your target is moving at 135,000km/h and boiling away before your eyes, you're going to need a team of brilliant and dogged scientists and engineers to get you there. This one-off film follows the Rosetta mission from its conception, using a mixture of location filming and animation.

27 JULY

Sinkholes: Swallowed Alive

Discovery, 10pm

IF EARTHQUAKES ARE the planet's machine guns, then sinkholes are its snipers: silent, unpredictable and deadly. This film uses eyewitness reports and geological insights to explore this alarming phenomenon. With one-fifth of the USA potentially at risk, the chances of getting swallowed up by the Earth could be greater than you realise.

FROM 5 AUGUST

Angry Planet

Eden, 6pm

FOR SOME PEOPLE, rollercoasters aren't thrilling enough. Storm-chaser George Kourounis is one of them, and this series follows him around the globe. Hurricanes, tornadoes, blizzards, volcanoes – any time you're fleeing a natural disaster, you'll probably pass George hurrying in the opposite direction. He's done well to survive for 39 episodes...

TIMANDRA HARKNESS is a stand-up comedian and a presenter on BBC Worldwide's YouTube channel Head Squeeze

PHOTO: THINKSTOCK X2, DISCOVERY NETWORK X3, BBC, UKTV

One World Trade Center is the tallest building in the western hemisphere

EDITOR'S CHOICE

6 AUGUST

Skyscraper High

Discovery, 8pm

THE TALLEST BUILDING in the West, and the most expensive ever constructed, One World Trade Center – the replacement for the Twin Towers – had a lot to live up to. As well as hitting the symbolic height of 1,776m (the year of the declaration of independence), it had to be the strongest, safest skyscraper ever built, and it took an army of architects, engineers and builders to turn it into reality.

Interviews with head of construction Steve Plate and chief architect Daniel Libeskind reveal how much innovative technology is at the heart of the $5 billion building. A bomb-proof base, blast-resistant glass and steel in 50-tonne chunks are just part of what went into '1WTC'. It's also taken the dedication of hundreds of workers for whom this is an emotional project, a gesture of defiance and hope in a city where most people have a personal connection to the events of 9/11. Beneath the simple facade lie human stories, engineering challenges and intriguing solutions, all rising from the ashes of Ground Zero.

FROM **5** AUGUST

Rise Of The Machines

Quest, 9pm

TODAY'S ENGINEERS HAVE produced some impressive machines – and inside every sleek exterior lurk hundreds of clever solutions to problems you may not even have thought of. Each of these hour-long films goes deep inside a state-of-the-art machine, from helicopters to racing cars, to explore the technological innovations involved.

10 AUGUST

The Sky At Night

BBC Four, 10.30pm

THIS MONTH'S EDITION of Britain's favourite astronomy series has a comet theme, as Chris Lintott and Maggie Aderin-Pocock take a closer look at the fiery snowballs. Once thought to be harbingers of doom, comets are now the target of bold space missions, and this programme includes a visit behind the scenes at Mission Control for Rosetta (see p56).

FROM **17** AUGUST

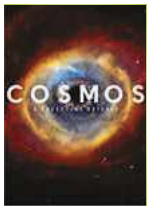
How The Earth Works

Discovery, 7pm

Liz Bonnin and Martin Pepper rock out in *How The Earth Works*

GEOLOGY MAY SOUND like a dry subject, practised by earnest men with tiny hammers. But if the object of their study gets restless, Los Angeles could be wiped out by a tsunami or earthquake. Doesn't seem so academic and dull now, does it? Presenters Liz Bonnin and Martin Pepper get their hands dirty as they attempt to find out what's going on underneath our planet's surface. Mount Everest is still growing – should we be worried? And what happens the next time Iceland erupts?

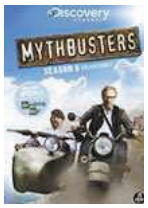
DVD & BLU-RAY



Cosmos Season 1

20th Century Fox Home Entertainment, £14

MISS THE REBOOT of the Carl Sagan classic, presented by Neil De Grasse Tyson? Now you can own it on DVD, complete with science history animations by Seth '*Family Guy*' MacFarlane.



Mythbusters Season 8

Discovery, £17.75

IN THIS 10TH anniversary season, James Cameron helps Adam and Jamie investigate the scientific realism of *Titanic*, and there's also a *Breaking Bad* special with Vince Gilligan and Aaron Paul.

ONLINE

YOUTUBE

Smashing Physics

bit.ly/SmashingPhysics

PHYSICIST JON Butterworth talks at London's Royal Institution on the topic of his recent book – with Professor Brian Cox to help him field some very smart questions from the audience.

YOUTUBE

Maths Puzzle: Back To Black

bit.ly/MathsBacktoBlack

NO, THIS ISN'T a rare Amy Winehouse foray into number theory. Instead, Dr James Grime sets a quirky puzzle, then flips a lot of game pieces from black to white and back again, so you don't have to.

YOUTUBE

Party Poppers Contain Primary Explosives!

bit.ly/PartyPoppers

WHAT MAKES PARTY poppers go bang? Explosives, of course, as Fran Scott demonstrates. Really, do not try this at home. You don't have the expertise, protective kit or insurance that Fran has...

LISTEN

BBC RADIO PROGRAMMES

WITH TIMANDRA HARKNESS

AUGUST

Robin Ince investigates self-help books

Heal Thyself: A History Of Self-Help

BBC Radio 4, dates TBC

ROBIN INCE READS a lot of books. In this new series he takes a look at a publishing genre in which authors claim to apply the insights of psychology to everyday life – the self-help book. But just how helpful are such tomes, really?

FROM 5 AUGUST

The Listeners

BBC Radio 4, 11am

IF YOU HEAR this programme, then you must listen to the radio, at least occasionally. But for some people, listening is central to what they do – it's their job. Their vocation, even. The series that takes a look at those who listen returns with three new episodes.

FROM 9 AUGUST

Damming Afghanistan

BBC World Service, 9/10 August, various times

THE HELMAND VALLEY Dam Complex could transform southern Afghanistan. But can US engineers complete it in time? It's 50 years since the Morrison-Knudsen company first arrived with Americans hoping to dam the valley, and many schemes have floundered.

Can the Helmand Valley ever be dammed?

FROM 9 AUGUST

The Forum: Bubbles

BBC World Service, 9/10 August, various times

PHYSICIST AND *FOCUS* columnist Helen Czerski, engineer Constantin Coussios and artist Bradley Hart join Bridget Kendall to talk about bubbles: bubbles in the ocean, bubbles in engineering and bubbles in, er, bubble wrap...

PODCAST

5 Live Science

bbc.co.uk/podcasts/series/drkarl

EVEN IF YOU'RE a BBC Radio 5 Live listener, you may have missed the station's regular science slots. Dr Karl hosts late night science chat, while the Naked Scientists cover essential science news each week. Catch up on what you've missed via the podcast.

TOUCH

SMARTPHONE & TABLET APPS

WITH KATE RUSSELL

QuakeFeed

iOS 5 or later, iPhone, iPad and iPod touch, Artisan Global LLC, free

THE USA'S NATIONAL Earthquake Information Center (NEIC) records about 50 earthquakes a day around the world, but there are millions more every year too weak to be recorded. You can keep tabs on seismic activity with the free iOS app Quakefeed. As well as alerts for global quakes above magnitude-6, there's a map view and articles to help you understand more about this natural phenomenon. For Android users a similar app, Earthquake Alert!, covers tremors over magnitude-4.5 and can be downloaded free from the Play Store.

iSeismometer

Android 2.2 or later, iOS 3.0 or later, Objectgraph, free

THE LARGEST RECORDED earthquake was magnitude-9.5, experienced in Chile in 1960. It's unlikely you'd be whipping out your smartphone if you were caught up in that kind of quake, but if you do ever have cause to think you can feel the Earth moving where you are, then iSeismometer is a free app that turns your phone into – you guessed it – a seismometer. It detects vibrations in real time via the accelerometer, displaying the strength of the tremor on a graph. The app is also available in the form of a mobile website at m.iseismometer.com, so it can be used on any mobile device that has the ability to register vibrations (such as a Windows smartphone).

myVolcano

iOS 6 or later, iPhone, iPad and iPod touch, British Geological Survey, free

ONE COMMON CAUSE of earthquakes is volcanic activity, and the British Geological Survey wants your help to gather data about any in your area. myVolcano is a free iPhone app that lets people share photographs and descriptions of volcanic hazards. If you want to collect samples to send to the researchers, the app will help you do this scientifically. And if you're missing the vital ingredient required to participate in this project – ie, you don't happen to have an exploding mountain near you – there's also a map showing you where to find the known volcanoes of the world. Just don't get too close or you could void your phone's warranty!

KATE RUSSELL is a technology journalist and BBC *Click* presenter

PHOTO: BBC, MUSADEQ SADEQ/WIKIPEDIA, FDECOMITE/FLICKR, THE EDINBURGH FESTIVAL FRIDGE SOCIETY, THINKSTOCK, RAFAEL ALEIXO/FLICKR

VISIT

EVENTS & EXHIBITIONS

WITH JHENI OSMAN

23 JULY–9 NOV

Stranger Than Fiction

Science Museum, London, www.sciencemuseum.org.uk

MIXING FACT AND fiction, science and art, this photo exhibition by Joan Fontcuberta looks at everything from constellations to fossils to a Finnish monastery where monks are said to perform miracles.

FROM 24 JULY

Extreme Engineering

Cambridge Science Centre, £3.50, www.cambridgesciencecentre.org

DISCOVER HOW THE Burj Khalifa was built, how shrinking electronics are changing our lives, and how to slow down a bullet.

24 JULY–2 NOV

Discovering Tutankhamun

Ashmolean Museum, University of Oxford, £10, www.ashmolean.org

THIS ANCIENT EGYPTIAN boy king rose to modern-day fame because of his well-preserved tomb. Find out about the hunt for the tomb and see original drawings and photographs from the dig.

6 AUGUST

3D Printing And Design

Royal Institution, London, 10am–4pm, ages 16–18, rigb.org

FROM FASHION TO F1 cars, 3D printing is at the heart of modern design and manufacturing. Get involved at this 3D printing workshop.

8 AUGUST

Byte-Sized Computing For Grown-Ups

Royal Institution, London, 10am–4pm, over 18s, rigb.org

THIS ONE-DAY COURSE gives you a chance to play with codes and computer graphics, and solve problems using basic programs.

14 AUGUST

Meridian Time Breach

Royal Observatory Greenwich, 7pm–9pm, £12, rmg.co.uk

GET KITTED UP in your steampunk finery for a late opening of the Longitude Punk'd exhibition. Meet artists, peer through the Victorian Great Equatorial Telescope and try some Meantime Brewery ale.

Edinburgh Fringe Festival has plenty to entertain the scientifically minded

EDITOR'S CHOICE

1–25 AUGUST

Edinburgh Fringe Festival

Venues/times/prices vary, www.edfringe.com

TOUTING THE HASHTAG '#unbored', the Edinburgh Fringe promises big things. Shows with science and tech themes include Brain Training On Trial, Dead Ghost Star and Oliver Meech's When Magic And Science Collide 2.0 – expect incredible tricks inspired by astounding science at the latter. Plus, there's *The Infinite Monkey Cage*'s Robin Ince with Blooming Buzzing Confusion, and Prof Richard Wiseman with Experimental: The Show That Plays With Your Mind.

22 AUGUST

Dino Snores For Grown-ups

Natural History Museum, London, 7.30pm–9.30am, £175 (£160 members), over 18s only, www.nhm.ac.uk

AT THIS MUSEUM sleepover there's a forensics show, comedy and live music, before you bed down under Dippy the Diplodocus.

26 AUGUST

Understanding Human Speech

At-Bristol, 6pm–7pm, free, www.ideasfestival.co.uk

DISCOVER HOW RESEARCHERS are investigating our vocal chords, and how computers are helping people who've lost their voice.

28 AUGUST

City Of Lost Children

Peter Harrison Planetarium, Greenwich, 7pm, £7, www.rmg.co.uk

IN THIS SCI-FI film, a deranged scientist kidnaps children to steal the dreams he needs to prolong his life. Sweet dreams...

JHENI OSMAN is a science writer and the author of *100 Ideas That Changed The World* (BBC Books, £9.99)

READ

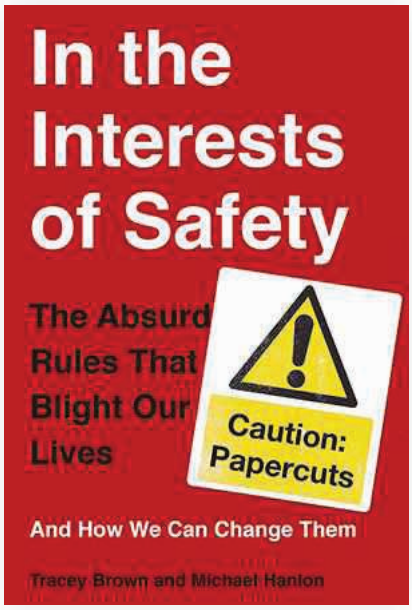
THE LATEST SCIENCE BOOKS REVIEWED

Ⓗ Hardback Ⓟ Paperback

In The Interests Of Safety

The Absurd Rules That Blight Our Lives And How We Can Change Them

Tracey Brown and Michael Hanlon
Sphere Ⓗ £12.99



'ELF AND SAFETY' is the stuff of legend. No throwing sweets to a panto audience, conker fights forbidden, no more than two children per adult at the pool. Often, this stuff is made up. But enough is true for it to be said that the ideal Batman villain would be Jack Nicholson with a clipboard as 'Health and Safety Man'.

You've heard this lament before. More intriguing is that Britain's Health and Safety Executive (HSE) often agrees: its own chair has called 'health and safety' one of the most dispiriting phrases in the language. The HSE even has its own myth-busters, who scrutinise cases such as 'Loose flowers and pots not allowed on graves,' where in fact health and safety is just a convenient excuse – in this case, one used to make maintenance easier.

So although good health and safety can save countless lives, new rules aren't necessarily a carefully calibrated response to an objective measure of potential harm. This idea that they might also mask self-interest – and that the evidence for them therefore needs scrutiny – drives Tracey Brown and Michael Hanlon's excellent, skeptical take on safety culture. Without good evidence, they say, the impulse towards prudence can curtail freedom and even make life more dangerous.

"The HSE's own chair has called 'health and safety' one of the most dispiriting terms in the language"

So this is not a rant, despite the 'why oh why?' character of the subtitle. It's a science-minded demand for proof, with oodles of examples – some deadly serious, some where the authors feel we are not safe enough. There are laughs too, such as the professor who questioned a police notice that, in the interests of safety, bikes chained to railings would be destroyed. Bikes, you see, *might* contain pipe bombs.

"When I confronted a senior policeman," the professor says, "with the fact that I had been unable to find a single instance of anyone, anywhere, ever having been killed by a bicycle bomb, he replied instantly with 'Yet'." Does the real motive, Brown and Hanlon wonder, have anything to do with scruffy bikes near smart addresses?

This is the age-old use of risk to assert control. If we invoke worst-case 'what ifs?' without proper evaluation, we become the slaves of nightmares. *In The Interests Of Safety* is not pro-danger, but it encourages us to pose the calm, yet subversive question: what's the evidence?

■■■■■

MICHAEL BLASTLAND is a writer and broadcaster who presents *The Human Zoo* on BBC Radio 4

MEET THE AUTHOR

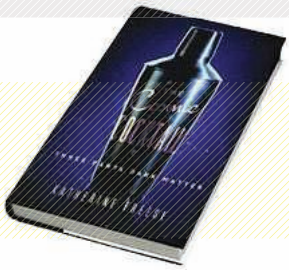
Tracey Brown

Why did you decide to write the book?
My co-author and I were at a conference together and we began talking about the ways in which we were confronting these rules. We started to contact people to ask why certain rules were in place. Why can't you photograph your children at the nativity play? Why do you have to restrict yourself to 100ml of fluids on a plane? If you ask for evidence, and you start asking people to be accountable for the rules that they impose upon us, then we're going to get a better standard of rules – and better safety.

We're often told not to use our mobile phones in petrol stations. Is there any truth to that one?
Absolutely not – there's not a single example of a mobile phone igniting petrol at a petrol station. If it was so dangerous, why would you allow anybody filling up their car to have their phone even in their pocket? In the early days of mobile phones, the operators and petrol companies didn't want to be blamed for something that they hadn't warned people about, so everybody put out warnings to cover their own backs rather than because there was any sound science behind them.

What was the most ridiculous rule you came across?
A chap cleaning the London Underground was told he couldn't wear a woolly hat during the winter for health and safety reasons. That's a good example of where somebody saw something new and unusual, didn't know what to make of it, and therefore just stuck the health and safety label onto the instruction to remove the hat.

MORE ON THE PODCAST
Listen to the full interview with Tracey Brown at sciencefocus.com/podcasts



The Cosmic Cocktail

Three Parts Dark Matter

Katherine Freese

Princeton University Press (H) £19.95

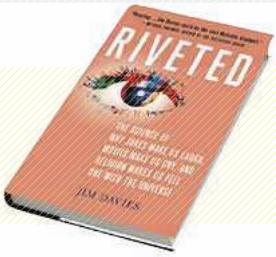
ONE PART NORMAL matter, three parts dark matter and 11 parts dark energy, on the rocks: astrophysical mixology is explained in *The Cosmic Cocktail*.

Dark energy is perhaps the biggest unsolved mystery in all of science. We've known the Universe is expanding since the 1920s, but it came as a shock when, in 1998, observations of distant stars revealed that this expansion was accelerating. We call whatever powers this mysterious acceleration 'dark energy'. Freese gives the low-down on the most cutting edge theories for this and other mysteries, punctuated with personal anecdotes.

Cosmology is a tough subject to tackle in a 200-pager. It's highly technical, yet abstract at the same time. If you want a light, easy read that will quickly familiarise you with the workings of the cosmos, this isn't it. But if you have some science background and want to improve your overall understanding of the Universe without reaching for a textbook, this could be just the thing. If this book was a cocktail it would be a dry vodka martini: it might help you understand the Universe better, but it's not for the faint-hearted.

■■■□□

Ruth Angus is a PhD student researching exoplanets at Oxford University



Riveted

The Science Of Why Jokes Make Us Laugh, Movies Make Us Cry And Religion Makes Us Feel At One With The Universe

Jim Davies

Palgrave Macmillan (H) £16.99

I'VE BECOME FASCINATED by a Facebook group about thermostats: in contrast, I simply cannot drum up any interest in the World Cup. In this book, Jim Davies aims to develop a theory of why we get engaged by certain topics and ideas.

The book is lively and opinionated but, ironically, hard to get caught up in – partly because many of his arguments simply don't quite follow. When discussing how we are "hardwired for socialising," for instance, he argues that the 'prototypical alien' described by 'alien abductees' is informed by the way infants see female faces – blurry and grey, with no noses or mouths. But there is evidence that babies are good at discerning their mothers' faces. 'Prototypical aliens' also vary with culture. Davies describes those that abduct people in the US; aliens described as abducting people here in the UK are tall, blonde and handsome, and harder to account for by models of infant vision.

We have struggled in the behavioural sciences to develop general laws for human likes and dislikes. I fear that the struggle continues.

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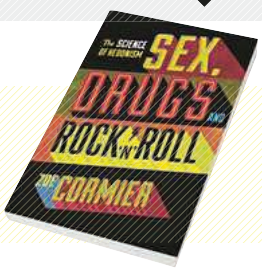
Sophie Scott is deputy director of UCL's Institute of Cognitive Neuroscience



Sex, Drugs And Rock n' Roll

The Science Of Hedonism

Zoe Cormier

Profile Books (P) £12.99

WRITTEN BY ONE of the commandos from Guerilla Science, a group that seeks to boost public appreciation of science, this book is a romp through three topics that preoccupy western youth, each with its own section. The style is tabloid, punctuated with bizarre factoids and images that are intended to tweak curiosity rather than present a core thesis – more of a dim sum of the weird and wonderful than a full banquet.

There are some occasional clangers (nerve impulses are not electrical sparks) that undermine the book's scientific credibility, but in fairness it is perfect to dip in and out of for tasty morsels. It's apparently been written to "challenge preconceptions of science and scientists as unintelligible, dull men in white coats"; however that cliché no longer holds today, with more popular science in the media than ever before.

To paraphrase online comic Cyanide & Happiness, this is a book for people who say they love science when in fact they just want to stare at the sexy, flashy bits as it walks by. Still, it makes a great source of after-dinner "did you knows?"

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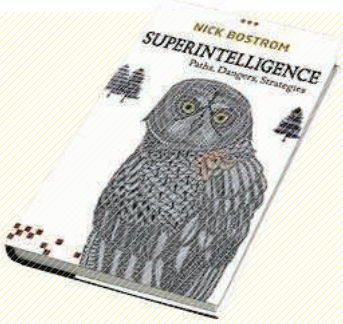
PROF BRUCE HOOD is the author of *The Domesticated Brain* (Pelican)



Superintelligence

Paths, Dangers, Strategies

Nick Bostrom

Oxford University Press (H) £18.99

MODERN TECHNOLOGY CAN be deadly. Right *now*, someone just died in a car crash – and right *now*, someone was just saved by the computer in their vehicle keeping them safe. So if an Oxford philosopher was to write a book castigating a technology that could harm humans, one might suppose they would focus on motor vehicles, while praising computer intelligence. Apparently not.

Superintelligence is an unconvincing trudge through the same old "computers are going to take over the world and kill us all" territory that forms the plot of many Hollywood movies. Despite copious notes, there is little understanding of the computer science he references; indeed Bostrom admits: "Many of the points made in this book are probably wrong."

It's such a painful read, with so little reward, that one wonders why we shouldn't read a science fiction novel instead. The science would be more accurate, the doomsday prophecies – and remedies to them – more coherent, and it would be far more entertaining.

■■□□□

Peter J Bentley is a computer scientist and author of *Digitized*

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MINDGAMES

Test your knowledge with our Big Quiz set by **James Lloyd**

BBC FOUR Don't miss *Only Connect*, a brain-bending quiz hosted by Victoria Coren on BBC Four – see radiotimes.com for details

1 **In June, the first transatlantic 'scent message' was exchanged between Paris and New York. What smells were transmitted?**

a) Chocolate and roses
b) Coffee and croissants
c) Champagne and macaroons

2 **According to recent research, why do koalas hug trees?**

a) To camouflage themselves better
b) To coat their soft underbellies in insect-repelling sap
c) To keep cool

3 **Scientists in the States have suggested that the facial features of our male ancestors evolved for what reason?**

a) To enable them to chew on fruit and vegetables
b) To protect them from injury during fist fights
c) To intimidate rivals and predators

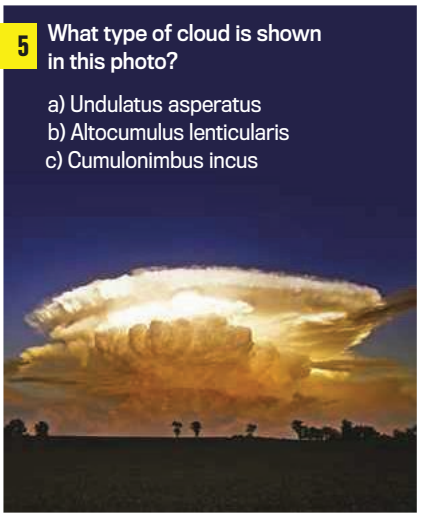
4 **What's the term that describes someone with extra fingers or toes, as in this X-ray of a six-fingered boy?**

a) Polydactyl
b) Multidigital
c) Superdextral

If only England goalkeeper Joe Hart had this condition...

5 **What type of cloud is shown in this photo?**

a) Undulatus asperatus
b) Altocumulus lenticularis
c) Cumulonimbus incus



6 **Eugene Goostman, a chatbot controversially said to have passed the Turing test in June, was a simulation of whom?**

a) A 13-year-old Ukrainian boy
b) A 78-year-old Dutch grandfather
c) A 42-year-old American professor

7 **Complete the recent headline: "Mountain blasted to build _____"**

a) Telescope
b) Laboratory
c) Railway

8 **Psychologists at the University of Oxford have found that salad tastes better when arranged to look like what?**

a) Famous faces
b) Abstract paintings
c) Iconic buildings

9 **A recent study has found that numerous spider species catch and eat what type of animal?**

a) Lizards
b) Monkeys
c) Fish

10 **Google recently released its augmented reality Glass specs in the UK. Which of these isn't an early app for the eyewear?**

a) Race Yourself, which allows you to compete against a virtual avatar
b) Celeb Spotter, which overlays the last known locations of your favourite celebrities
c) Word Lens, which translates foreign signs into English

11 **Using DNA from a living relative, an artist recently created a replica of which famous body part?**

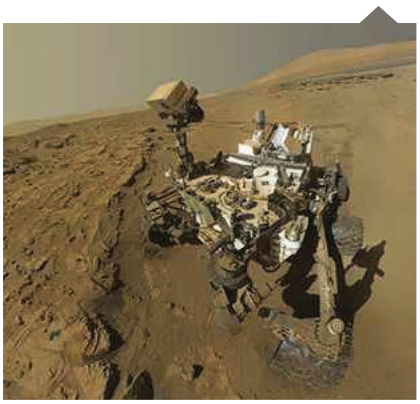
a) Einstein's brain
b) Vincent van Gogh's ear
c) Elvis Presley's pelvis

12 **Complete the recent headline: "_____ _____ can lift three times own body weight"**

a) Elephant's trunk
b) Ant's mandibles
c) Frog's tongue

13 **In June, NASA's Mars Curiosity rover celebrated what landmark?**

a) One Martian year on the planet
b) 1,000 successful rock sample analyses
c) 100 miles travelled across the surface



Curiosity is still studying Mars's Gale Crater

PHOTO: NICHOLAS T/FLICKR, NASA, MAGNUS MANSKE

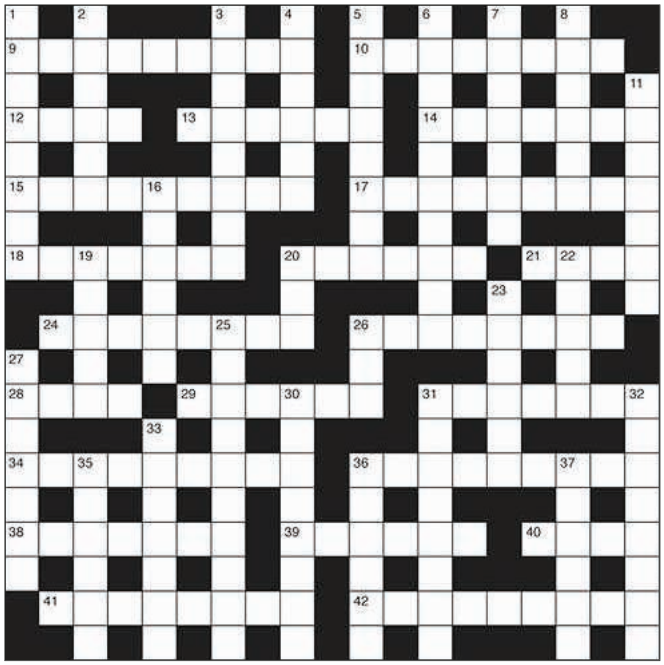
QUIZ ANSWERS

1c, 2c, 3b, 4a, 5c, 6a, 7a, 8b, 9c, 10b, 11b, 12c, 13a

HOW DID YOU SCORE?

0-4 A NIGHT IN MILTON KEYNES **5-9** A WEEK IN MARBELLA **10-13** A MONTH ON MARS

FOCUS CROSSWORD No 167



ACROSS

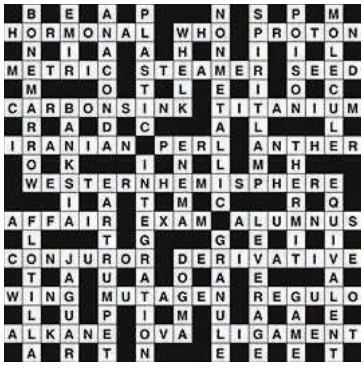
9 Brewed tea with garlic and gristle (9)
10 Excess in the polar variation (8)
12 Not odd to be found in the Venn diagram (4)
13 A new spirit, and a pain (6)
14 Game to play at a scan (7)
15 Sort out tumult, aim to reach deadline (9)
17 Chemical link between building style and spy (5,4)
18 Charlatan puts most of kingdom in charge (7)
20 Roll with it – Frenchman is in the picture (6)
21 Initially gives everything bitterness (4)
24 Snug tent made out of metal (8)
26 My name explains my own name, in characters (8)
28 Repeat in the chorus (4)
29 Input device is vital at home (6)
31 Damp oil used with qualification (7)
34 Turn mural round during racket – that's tough (9)
36 Warn Lois about Dutch emissions (5, 4)
38 Trendy girl starts to get fruit (7)
39 Copper finds unusual toxic resin (6)
40 Left at old church to reach lake (4)
41 Preservative to make nail better (8)
42 Hardly only D minor, say, that develops backbone (9)

DOWN

1 He would put clues out about plan (8)
2 Rage about book being silver (6)
3 Magic net – terribly attractive (8)
4 To sing with a fellow is a gas (6)
5 A part is played by one insect lover (8)
6 Errand boy puts recent change in proportion (10)
7 Working in shop, having caught teaching method (7)
8 Loud snore upsets entire city (6)
11 Dan's forced to travel as a carrier (7)
16 I am turning anger into an illusion (6)
19 Quiet cry of pain, a bit marsupial (5)
20 Prohibit British article (3)
22 Group of atoms having main problem with oxygen (5)
23 Manage to get round rare artisan (6)
25 Mother fixed large house gauge (10)
26 Deposit slander (3)
27 Almost extremely rude about vegetation (7)
30 Yearn to put ice cream in part of tree (4,4)
31 Perform old eastern ceremony in rock (8)
32 Led heady rally in compound (8)
33 Clay used around fringe of old science (7)
35 City roots out victory (6)
36 Series about physics theory (6)
37 Is work too much for a woodlouse? (6)

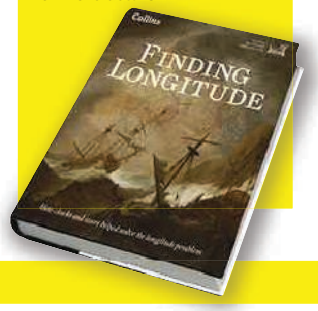
SOLUTION TO CROSSWORD No 164

Kathy Humphrey, Ian Bell, Philip Cooper, Roger Shilcock and Brian Duncan each solved issue 268's puzzle and receive a copy of *David Attenborough's Natural History Museum Alive* on DVD (Go Entertain, £12.50).



WIN! *FINDING LONGITUDE*

The first five correct solutions drawn will each win a copy of *Finding Longitude* by Richard Dunn and Rebekah Higgitt (Collins, £20). Entries must be received by 5pm on 21 August 2014. See below for more details.



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Post entries to *BBC Focus Magazine*, August 2014 Crossword, PO Box 501, Leicester, LE94 0AA or email a scan of the completed crossword or a list of answers to august2014@focuscomps.co.uk by 5pm on 21 August 2014. Entrants must supply name, address and phone number. Immediate Media, publisher of *BBC Focus Magazine*, may contact you with details of our products and services or to undertake research. Please write 'Do Not Contact' on your email or postal entry if you do not want to receive such information by post or phone. Please write your email address on your postal entry if you would like to receive such information by email.

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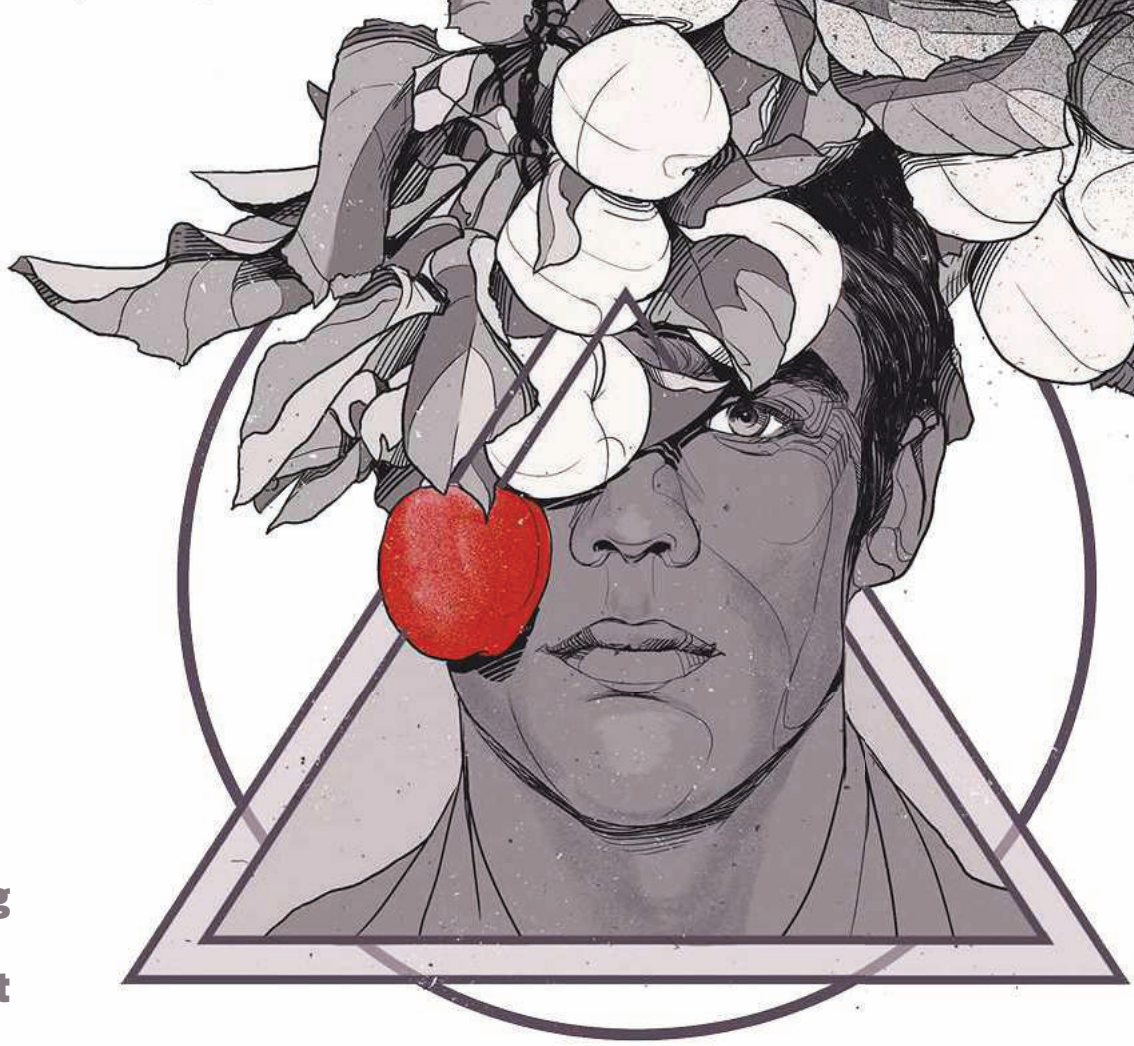
HOLLYWOOD SCIENCE

Separating science fact from movie fiction



Mind control in THE GIVER

IMAGINE A WORLD where no-one ever disagrees, dissents or dares to be different. Where everyone likes the same music, follows the same football team (Coventry City) and concurs that Morris dancing should be made illegal. It sounds very harmonious, but wouldn't such a world be a dull place? That is, however, life as normal in Phillip Noyce's sci-fi flick *The Giver*. In this dystopian world, individuality and choice have been replaced by colourless conformity. Only one man, Jonas, is prepared to buck the trend. So why do some of us toe the line, while others dare to be different?

"People have a strong tendency to conform," says psychologist Vasily Klucharev from the University of Basel in Switzerland, "but they differ in the extent to which they do so." Studies have shown that people often revise their opinions to match those of their peers when they realise their views are different. Klucharev has identified a brain region, the posterior

"People have a strong tendency to conform, but differ in the extent to which they do so"

medial frontal cortex, that is involved. His theory is that when individuals deviate from the group, the region generates an error signal, triggering a cascade of neural events that leads us to conform. "In evolutionary terms, it's a very old region of the brain, so we do this without realising," he says.

But conformity can be manipulated. When Klucharev dulled the activity of this brain region using powerful electromagnetic pulses, he found his volunteers were less likely to conform. Asked to rate how attractive various female faces were, they stuck to their guns and weren't swayed by the opinions of others. So perhaps wayward brain activity can explain why I'm the only woman on Earth not to fancy Harry Styles. It can work the other way, too. When brain levels of the neurotransmitter dopamine are boosted by the attention-deficit hyperactivity disorder drug methylphenidate, people are more likely to adopt the views of the group, a Danish study found.

All of which is interesting, but still a far cry from the mass mind control of *The Giver*. "If you want to manipulate a whole country, you don't need neuroscience," says Russian-born Klucharev. "You can use the media. If you switch on the TV in Moscow, you see only one point of view. You face a crowd of people all of whom have the same opinion, and you experience the internal conflict of being different." This leads the majority to adopt the same viewpoint. "It's propaganda," says Klucharev, "and it's very effective."

So do I really hold the views I think I do, or is my brain forcing me to fall in step with the majority? It should be easy enough to find out: I'll just stick on some One Direction and see if I still get the urge to gag... ■

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

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